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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

PAPERS,

ABSTRACTS OF PAPERS,

AND

REPORTS OF THE PROCEEDINGS

OF

THE SOCIETY,

FROM NOVEMBER 1878 *TO NOVEMBER* 1879.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXIX. *November* 8, 1878. No. 1.

LORD LINDSAY, M.P., F.R.S., President, in the Chair.

The Rev. J. M. Coates, The Goddards, Moulton, Spalding; and

B. G. Jenkins, Esq., 4 Buccleuch Road, West Dulwich; were balloted for and duly elected Fellows of the Society.

Dr. C. Brühns, The Observatory, Leipzig;
Baron H. von Dembowski, Gallarate;
G. W. Hill, Esq., New York; and
Prof. E. Schönfeld, The Observatory, Bonn;

were balloted for and duly elected Associates of the Society.

Observations at the Adelaide Observatory. By C. Todd, Esq., Director of the Observatory.

(*Extract from letter to the Astronomer Royal.*)

By to-day's mail I send you the following for the Royal Astronomical Society, viz.:—

Observations of transits, occultations, and eclipses of *Jupiter's* satellites in 1877.

Total eclipse of the Moon on the morning of February 28, 1877.

Partial eclipse of the Sun on February 2, 1878.

Transit of *Mercury* on May 6, 1878.

A few sets of east and west parallax observations of *Mars* at opposition were taken, which I must send you in a future letter. Some sets comprise a large number of differential measurements of R.A., but my chronograph was not very good, and the instrument required a better clamp in R.A. The observations may, however, possess some value, and I will therefore send them for what they are worth. With a better R.A. clamp, which I will make, and a new chronograph I have made since, I think I shall be able to secure better results in future.

With regard to *Jupiter*, the visibility of the satellites through the edge of the planet has been very carefully looked for; and on two occasions I felt quite certain I saw the satellite at occultation within the disk, viz. on June 19, at occultation disappearance of Satellite II, and on July 2, at disappearance of Satellite I. Mr. Ringwood also saw the same phenomenon at the disappearance of Satellite II on August 29. I thought I could see Satellite III through the limb at reappearance on June 9, and Satellite II at disappearance on July 21, but could not be certain. In every other case the occultation was perfect at the limb. On June 19 Satellite II was visible through the white belt south of equator, and on July 2 Satellite I was seen for the space of one minute through the southern dark belt. It would be interesting to know whether this has been seen by other observers. The definition on each occasion was very good, or I should think I might be deceived.

I may mention that the other evening (July 5) I was surprised to see Satellite IV in transit appear as a dark spot instead of the usual bright point when on the less illumined surface near the edge of the planet; in fact it was at entry nearly as black as its shadow, which was just passing off on the other side. This I know has been seen before, both with Satellites III and IV, and must, I presume, be attributed to one side of the satellite reflecting less light than the other, or else to some violent changes in its atmosphere. Before it came on to the disk I noticed that it was fainter than usual.

It may be worth recording, perhaps, that in 1877 the dark belts of *Jupiter* had not, to my eye at least, the same bright metallic lustre that they had in 1876, but appeared to be covered with a thin haze and looked foggy. And this year the southern dark belt is seldom so highly coloured or so well defined as the northern one. I send you a few pencil sketches, which, however, possess very little merit. Please remember, when thinking how little I do, that I am also Postmaster-General and Superintendent of Telegraphs. My meteorological work is well advanced, but comes very slowly from the printer, especially when Parliament is in session. I send you the observations for January 1878, in which you will see I have made several alterations—I trust improvements. The rain stations are differently grouped, and the returns show at a glance the rainfall over different districts within and without the tropics, extending from the north to the south coast (27° of latitude and over 12° of longitude). The 1877 observations are nearly all printed and will be sent to you shortly.

Adelaide, South Australia,
8 *August* 1878.

Transits, Occultations, and Eclipses of Jupiter's Satellites, during the Year 1877.

(Observers—T., Mr. Todd; R., Mr. Ringwood.)

Ref. No.	Date and Time.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time. h m s	Corresponding G.M.T. h m s	Time by *Nautical Almanac.* h m s	Apparent Error of *Nautical Almanac.* m s	Power.
1				First seen	8 53 27·1	23 39 5·8	23 39		200
2	June 1 8 54	T.	I Sh. I.	About bisected	8 54 29·1	23 40 7·8			"
3				Internal contact	8 55 39·1	23 41 17·8			"
4				First contact	9 17 52·1	0 3 30·8	0 5		"
5	9 20	T.	I Tr. I.	Bisected	9 19 58·1	0 5 36·8			"
6				Internal contact	9 21 36·6	0 7 15·3			"
7				Internal contact	11 5 9·9	1 50 48·6			"
8	11 6	T.	I Sh. E.	Bisected	11 6 39·9	1 52 18·6			"
9				Limb complete	11 8 13·9	1 53 52·6	1 54		"
10				Internal contact	11 30 46·4	2 16 25·1			"
11	11 32	T.	I Tr. E.	Bisected	11 32 12·9	2 17 51·6			"
12				External contact	11 34 19·9	2 19 58·6	2 21		"
13				First seen	7 34 52·3	22 20 31·0	22 27		"
14	June 2 7 40	T.	III Oc. R.	About bisected	7 38 52·3	22 24 31·0			"
15				External contact	7 42 32·3	22 28 11·0			"

Remarks.

Ref. No.
1 Limb slightly indented.
10 Very exact.
12 Good observation.

Ref. No.
13, 14, 15 A little late. Planet ill defined and hazy.

Ref. No.	Date and Time.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding G.M.T.	Time by *Nautical Almanac.*	Apparent Error of *Nautical Almanac.*	Power.
					h m s	h m s	h m s	m s	
16				First seen	8 51 44·2	23 37 22·9	23 39		200
17	June 2 8 53	T.	I Oc. R.	About bisected	8 52 55·2	23 38 33·9			,,
18				External contact	8 54 40·2	23 40 18·9			,,
19	June 3 9 43	T.	II Sh. I.	External contact			0 25		,,
20				Internal contact	9 43 31·8	0 29 10·5			,,
21				External contact	10 26 1·7	1 11 40·4	1 12		,,
22	10 28	T.	II Tr. I.	Bisected	10 28 21·7	1 14 0·4			,,
23				Internal contact	10 30 21·7	1 16 0·4			,,
24	June 9 7 20	T.	III Ec. D.		7 20 34·1	22 6 12·8	22 4 40	−1 32·8	125
25	8 9	T.	I Ec. D.		8 8 45·0	22 54 23·7	22 54 3	−0 20·7	,,
26				First seen	10 35 38·7	1 21 17·4	1 23		200
27	10 37	T.	I Oc. R.	Bisected	10 37 8·7	1 22 47·4			,,
28				External contact	10 38 38·7	1 24 17·4			,,
29				First seen	10 52 33·7	1 38 12·4	1 45		,,
30	10 52	T.	III Oc. R.	Bisected	10 56 8·7	1 41 47·4			,,
31				External contact	11 0 3·7	1 45 42·4			,,
32				Very dim	6 30 32·5	21 16 11·2			125
33	June 12 6 30	R.	II Ec. D.	Just visible	6 30 52·5	21 16 31·2			,,
34				Disappeared	6 31 2·5	21 16 41·2	21 16 9	−0 32·2	,,
35				First seen			0 23		,,
36	9 36	R.	II Oc. R.	Past bisection	9 36 53·8	0 22 32·5			,,
37				External contact	9 37 19·3	0 22 58·0			,,

38	June 16	10 3	T.	I	Ec. D.		10 3 13·1	0 48 51·8	0 48 21	−0 30·8		,,
39		11 20	T.	III	Ec. D.		11 19 43·5	2 5 22·2	2 3 22	−2 0·2		,,
40						External contact	7 12 3·1	21 57 41·8	21 59			200
41	June 17	7 13	T.	I	Tr. I.	Bisected	7 13 33·1	21 59 11·8				,,
42						Internal contact	7 15 23·1	22 1 1·8				,,
43						Internal contact	9 21 56·0	0 7 34·7				,,
44		9 24	T.	I	Sh. E.	About bisected	9 23 3·0	0 8 41·7				,,
45						Last seen	9 24 9·0	0 9 47·7	0 11			,,

Remarks.

Ref. No.

18 Good observation.
19 Lost; came too late.
20 Not good; badly defined; sky hazy.
21, 22, 23 Good; fair definition.
24 Very exact; planet wretchedly defined.
25 Good observation.
26, 27, 28 Not well defined.
29, 30, 31 May be a little late. Good. Planet not very well defined; clouds passing. Had an impression that I saw half the satellite through edge of planet.
33 A mere speck of light.
35 Lost, through clouds.
37 Doubtful.

Ref. No.

38 Very good; disappearing close to planet, which was beautifully defined. Closeness to planet may affect time of disappearance.
39 Very exact; close proximity to planet may, however, affect observation; definition splendid.
40, 41, 42 The satellite entered the planet on the northern margin of the dark belt north of the planet's equator, and its shadow, which preceded it, was not seen till $7^h\ 16^m$, when it appeared in almost tangential contact with satellite, which could be followed for a considerable space across the disk of the planet; the shadow was very sharply defined. Passing clouds partially obscured the planet at times, and the limb was often wavy and tremulous, but the times noted were considered good.
43, 44, 45 Five minutes before internal contact of shadow, the shadow and satellite appeared to be in contact, both, but especially shadow, being sharply defined.

Ref. No.	Date and Time.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding G.M.T.	Time by *Nautical Almanac.*	Apparent Error of *Nautical Almanac.*	Power.
					h m s	h m s	h m s	m s	
46				Internal contact	9 24 29·0	0 10 7·7			200
47	June 17 9 27	T.	I Tr. E.	Bisected	9 25 51·0	0 11 29·7			,,
48				External contact	9 27 43·0	0 13 21·7	0 14		,,
49				First seen	6 45 59·0	21 31 37·7	21 33		125
50	June 18 6 47	T.	I Oc. R.	About bisected	6 47 0·5	21 32 39·2			,,
51				External contact	6 48 19·5	21 33 58·2			,,
52				External contact	9 1 18·1	23 46 56·8			200
53	June 19 9 5	R.	II Oc. D.	About bisected	9 3 29·6	23 49 8·3			,,
54				Internal contact	9 5 14·6	23 50 53·3	23 50		,,
55				Last seen	9 5 29·1	23 51 7·8			,,
56				External contact	8 55 53·8	23 41 32·5	23 42		,,
57	June 24 8 57	T.	I Tr. I.	Bisected	8 57 11·8	23 42 50·5			,,
58				Internal contact	8 58 43·8	23 44 22·5			,,
59				First seen	9 2 34·8	23 48 13·5	23 49		,,
60	9 4	T.	I Sh. I.	About bisected	9 3 54·8	23 49 33·5			,,
61				Internal contact	9 5 39·8	23 51 18·5			,,
62				First seen	8 37 6·3	23 22 45·0	23 23 4	+0 19·0	,,
63	June 25 8 37	R.	I Ec. R.	Quite distinct	8 37 37·8	23 23 16·5			,,
64				Full blaze	8 39 17·8	23 24 56·5			,,

65						Internal contact	6 54 38·0	21 40 16·7			"
66	June 27	6 58	T.	III	Tr. E.	About bisected	6 57 57·5	21 43 36·2			"
67						External contact	7 1 59·0	21 47 37·7	21 51		"
68						Internal contact	7 41 9·0	22 26 47·7			"
69		7 45	T.	III	Sh. E.	About bisected	7 44 59·0	22 30 37·7			"
70						Limb complete	7 48 4·0	22 33 42·7	22 36		"
71	June 28	6 47	T.	II	Sh. I.	External contact			21 30		"
72						Nearly bisected	6 47 20·1	21 32 58·8			"
73						Internal contact	9 1 26·1	23 47 4·8			"
74		9 4	T.	II	Tr. E.	About bisection	9 4 30·4	23 50 9·1			"
75						External contact	9 6 19·9	23 51 58·6	23 53		"

Remarks.

Ref. No.

49 Considered rather late; thin fog clouds over sky.

52 Good.

54, 55 Very good; the satellite disappeared behind white cloud belt, but did not finally disappear till within the limb, or about 14½ˢ after time noted of internal contact.

56, 57, 58, 59, 60, 1 Good; satellite and shadow entered on dark belt north of equator; definition of planet superb.

62, 63, 64 A mere speck. Very good; well defined; Moon close by.

65, 66, 67 Difficult observation, owing to bad definition of satellite; external contact good.

68, 69, 70 Considered good; clouds passing.

72 Cloudy; internal contact not seen.

73 Very exact.

Ref. No.	Date and Time.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time. h m s	Corresponding G.M.T. h m s	Time by *Nautical Almanac*. h m s	Apparent Error of *Nautical Almanac*. m s	Power.
76				Internal contact	9 28 6·9	0 13 45·6			200
77	June 28 9 30	T.	II Sh. E.	About bisection	9 29 38·9	0 15 17·6			,,
78				Limb complete	9 31 33·4	0 17 12·1	0 18		,,
79				External contact	7 56 59·0	22 42 37·7			,,
80	July 2 8 0	T.	I Oc. D.	About bisected	7 58 39·0	22 44 17·7			,,
81				Internal contact	8 1 15·7	22 46 54·4	22 46		,,
82				Disappearance	8 2 13·5	22 47 52·2			,,
83				Internal contact	7 17 15·2	22 2 53·9			,,
84	July 3 7 20	T.	I Tr. E.	About bisected	7 18 28·2	22 4 6·9			,,
85				External contact	7 20 15·2	22 5 53·9	22 8		,,
86				Internal contact	7 36 18·2	22 21 56·9			,,
87	7 38	T.	I Sh. E.	About bisected	7 37 30·2	22 23 8·9			,,
88				Limb complete	7 39 39·2	22 25 17·9	22 28		,,
89				External contact	8 34 46·2	23 20 24·9	23 22		300
90	July 5 8 37	T.	II Tr. I.	Bisected	8 36 45·2	23 22 23·9			,,
91				Internal contact	8 38 44·2	23 24 22·9			,,
92				First seen	9 20 49·1	0 6 27·8	0 6		,,
93	9 23	T.	II Sh. I.	About bisected	9 22 27·6	0 8 6·3			,,
94				Internal contact	9 24 27·1	0 10 5·8			,,

95						Internal contact	11 17 18·0	2 2 56·7				200
96		11 20	T.	II	Tr. E.	About bisection	11 19 8·0	2 4 46·7				,,
97						External contact	11 21 31·5	2 7 10·2	2 9			,,
98						Internal contact	12 3 44·0	2 49 22·7				,,
99		12 6	T.	II	Sh. E.	Bisected	12 5 38·0	2 51 16·7				,,
100						Limb complete	12 7 55·5	2 53 34·2	2 54			,,
101	July 7	6 15	T.	II	Ec. R.		6 14 44·2	21 0 22·9	21 1 52	+1 29·1		,,
102						First seen	6 54 53·3	21 40 32·0	21 40 53	+0 21·0		,,
103	July 11	6 57	R.	I	Ec. R.	Quite distinct	6 55 18·3	21 40 57·0				,,
104						Full blaze	6 58 4·3	21 43 43·0				,,
105	July 14	8 51	T.	II	Ec. R.		8 50 38·0	23 36 16·7	23 37 50	+1 33·3		,,

Remarks.

Ref. No.

79, 80, 81, 82 The satellite disappeared behind the dark belt south of the equator, and was distinctly seen through the edge of the planet for the space of its full diameter, not finally disappearing till about one minute after internal contact, the occultation being effected at some distance within the limb. At $7^h\ 59^m\ 18^s$ and at $8^h\ 0^m\ 53^s$ the satellite was noted as partly behind or immersed in the planet and partly protruding as a small nipple on the limb.

85 Satellite passed off north dark belt.

87 Shadow traversed north dark belt.

89, 90, 91 Very good observation; both planet and satellite well defined. The satellite just within the bright band north of the dark belt.

92, 93, 94 Good observation; shadow very sharply defined. The satellite faintly visible opposite to a bright spot on south side of dark belt.

95, 96, 97 Internal contact a little early. Planet not so well defined as at ingress. Foggy.

98, 99, 100 Planet not very well defined, but observations considered good.

101 Good, caught first glimmer. Observed also by R. with a 4-inch object-glass, time noted being $6^h\ 15^m\ 21^s{\cdot}9$ A.M. T.

102, 103, 104 Planet not well defined, but observations considered good.

105 Very good; caught first glimmer.

Ref. No.	Date and Time.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding G.M.T.	Time by *Nautical Almanac.*	Apparent Error of *Nautical Almanac.*	Power.
					h m s	h m s	h m s	m s	
106				Internal contact	5 54 51·6	20 40 30·3			200
107	July 19 5 57	R.	I Sh. E.	About bisected	5 55 57·6	20 41 36·3			,,
108				Limb complete	5 57 27·6	20 43 6·3	20 46		,,
109				External contact	7 12 29·8	21 58 8·5			,,
110	July 21 7 15	T.	II Oc. D.	About bisected	7 14 48·8	22 0 27·5			,,
111				Internal contact	7 17 18·8	22 2 57·5	22 1		,,
112	11 28	T.	II Ec. R.	First seen	11 26 30·5	2 12 9·2	2 14 3	+1 53·8	,,
113				Full blaze	11 31 3·5	2 16 42·2			,,
114				First seen	6 46 51·8	21 32 30·5	21 40		,,
115	July 22 6 50	T.	III Oc. R.	About bisected	6 49 21·8	21 35 0·5			,,
116				External contact	6 53 11·8	21 38 50·5			,,
117				Becoming dim	7 4 1·8	21 49 40·5			,,
118	7 10	T.	III Ec. D.	Sensibly dimmer	7 5 32·8	21 51 11·5			,,
119				Disappeared	7 13 25·8	21 59 4·5	21 57 43	−1 21·5	,,
120	9 50	T.	III Ec. R.	First seen	9 48 33·6	0 34 12·3	0 38 25	+4 12·7	,,
121				Full blaze	9 58 1·6	0 43 40·3			,,
122				External contact	10 20 55·2	1 6 33·9	1 9		,,
123	July 24 10 20	T.	I Tr. I.	About bisected	10 22 27·7	1 8 6·4			,,
124				Internal contact	10 24 52·2	1 10 30·9			,,

125						First seen	11 9 29·1	1 55 7·8	1 56			"
126		11 10	T.	I	Sh. I.	About bisected	11 10 54·6	1 56 33·3				"
127						Internal contact	11 12 51·6	1 58 30·3				"
128	July 25	7 41	T.	I	Oc. D.	External contact	7 41 4·2	22 26 42·9				300
129						Disappeared	7 44 45·2	22 30 23·9	22 28			"
130						External contact	9 31 20·1	0 16 58·8				200
131	July 28	9 38	T.	II	Oc. D.	About bisected	9 33 58·1	0 19 36·8				"
132						Disappeared	9 37 9·1	0 22 47·8	0 21			"

Remarks.

Ref. No.

106, 107, 108 } Very good; shadow traversed dark band.

109, 110, 111 } Very good; planet well defined. Satellite disappeared a little south of southern dark belt, behind a bank of white cloud, and at times I thought I could see the whole of the satellite immersed in the planet up to internal contact.

112 Good; a mere speck of light.

114 Time late.

116 Good. Planet and satellite well defined.

117, 118, 119 } The disk of the satellite was very sharply defined. The time first noted is when I first observed an alteration in the outline of the disk, the altered form being well marked at the second time, when the shadow appeared to extend over nearly one-third of the disk. The satellite was reduced to a mere speck of light for at least a minute before disappearance, and I lost sight of it for a few seconds about 10 seconds before the time noted (119) but caught it again, and the time given must be very exact.

120 Good; seen instantly.

121 Disk perfect.

122, 123, 124 } Bad definition.

125, 126, 127 } External contact doubtful; definition wretched.

128, 129 } Not good, clouds interfering; satellite disappeared behind a bright white cloud belt.

130 Not very good.

131 Not very good.

132 Exact.

Ref. No.	Date and Time.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time. h m s	Corresponding G.M.T. h m s	Time by *Nautical Almanac*. h m s	Apparent Error of *Nautical Almanac*. m s	Power.
133				External contact	7 30 49·8	22 16 28·5			200
134	July 29 7 42	T.	III Oc. D.	About bisected	7 35 44·8	22 21 23·5			,,
135				Disappeared	7 41 24·8	22 27 3·5	22 22		,,
136				First seen	10 16 14·4	1 1 53·1	1 8		,,
137	10 17	T.	III Oc. R.	About bisected	10 20 4·4	1 5 43·1			,,
138				External contact	10 25 14·4	1 10 53·1			,,
139				First seen	6 28 17·5	21 13 56·2	21 13		,,
140	July 30 6 30	T.	II Sh. I.	About bisected	6 29 3·0	21 14 41·7			,,
141				Internal contact	6 31 3·0	21 16 41·7			,,
142				External contact	9 29 28·5	0 15 7·2			,,
143	Aug. 1 9 30	T.	I Oc. D.	About bisected	9 31 7·5	0 16 46·2			,,
144				Disappeared	9 32 34·5	0 18 13·2	0 16		,,
145				External contact	6 36 38·4	21 22 17·1	21 23		,,
146	Aug. 2 6 37	T.	I Tr. I.	About bisection	6 38 19·9	21 23 58·6			,,
147				Internal contact	6 40 3·9	21 25 42·6			,,
148	7 37	T.	I Sh. I.	External contact			22 19		,,
149				Internal contact	7 36 23·8	22 22 2·5			,,
150				Internal contact	8 48 27·6	23 34 6·3			,,
151	8 50	T.	I Tr. E.	About bisected	8 50 30·6	23 36 9·3			,,
152				External contact	8 52 58·6	23 38 37·3	23 39		,,

153							Internal contact						„
154			9	49	T.	I	Sh. E.	About bisected	9 46 57·0	0 32 35·7			„
155								Limb complete	9 48 15·0	0 33 53·7	0 36		„
156								First seen	5 58 6·5	20 43 45·2	20 45 23	+1 37·8	„
157	Aug.	8	6	0	R.	II	Ec. R.	Quite distinct	5 58 29·5	20 44 8·2			„
158								Full blaze ?	6 0 39·5	20 46 18·2			„
159								External contact	11 17 24·8	2 3 3·5			„
160			11	20	T.	I	Oc. D.	About bisected	11 19 11·8	2 4 50·5			„
161								Disappearance	11 21 15·8	2 6 54·5	2 4		„

Remarks.

Ref. No.

133 Good.
134 Good.
135 Exact.
136 A little late; badly defined.
138 Good, but planet badly defined.
139, 140, 141 Very badly defined; not considered good.
142, 143, 144 External contact considered late; disappearance very exact. Planet and satellite well defined. The satellite disappeared behind and about the middle of the dark belt south of the equator. The dark belts on either side of the equator were hazy and seemingly covered with a thin cloud. The occultation was perfect at limb. No appearance of satellite as it passed behind the planet, but the Jovian clouds appeared denser than usual.

Ref. No.

145, 146, 147 Very steady, and times noted considered very exact. The dark belts appeared to be covered with a thin film of cloud, or as if seen through fog.
149 Good. *Vide* description and sketch.
153 Lost; late.
154, 155 Not good.
156, 157, 158 Good.
159, 160, 161 External contact (159) very good, disappearance (161) very exact; steady and well defined. The occultation perfect; satellite not visible through limb. The brown belts have still the hazy appearance noted on previous nights—as if covered with a thin film of cloud.

Ref. No.	Date and Time.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time. h m s	Corresponding G.M.T. h m s	Time by *Nautical Almanac*. h m s	Apparent Error of *Nautical Almanac*. m s	Power.
162				External contact	8 24 40·9	23 10 19·6	23 12		200
163	Aug. 9 8 26	T.	I Tr. I.	About bisected	8 26 51·9	23 12 30·6			,,
164				Internal contact	8 28 25·9	23 14 4·6			,,
165				First seen	9 28 17·8	0 13 56·5	0 14		,,
166	9 30	T.	I Sh. I.	About bisected	9 28 59·8	0 14 38·5			,,
167				Internal contact	9 31 23·8	0 17 2·5			,,
168	Aug. 11 6 10	T.	I Sh. E.	About bisected	6 9 54·4	20 55 33·1			,,
169				Limb complete	6 11 25·4	20 57 4·1	21 0		,,
170				External contact	9 24 38·6	0 10 17·3	0 11		,,
171	Aug. 13 9 27	T.	II Tr. I.	About bisected	9 27 12·1	0 12 50·8			,,
172				Internal contact	9 30 13·1	0 15 51·8			,,
173	Aug. 15 8 35	T.	II Ec. R.	First seen	8 35 8·1	23 20 46·8	23 22 25	+1 38·2	,,
174				Full blaze?	8 40 30·6	23 26 9·3			,,
175				Internal contact	7 6 7·5	21 51 46·2			,,
176	Aug. 16 7 10	T.	III Tr. E.	About bisected	7 8 48·5	21 54 27·2			,,
177				External contact	7 12 37·5	21 58 16·2	22 1		,,
178				First seen	8 56 55·8	23 42 34·5	23 45		,,
179	9 0	T.	III Sh. I.	About bisected	8 59 35·3	23 45 14·0			,,
180				Internal contact	9 5 27·3	23 51 6·0			,,

181						External contact	10 13 22·2	0 59 0·9	1 2			"
182		10 16	T.	I	Tr. I.	About bisected	10 15 40·2	1 1 18·9				"
183						Internal contact	10 18 19·7	1 3 58·4				"
184						First seen	11 22 38·5	2 8 17·2	2 9			300
185		11 25	T.	I	Sh. I.	About bisected	11 25 0·0	2 10 38·7				"
186						Internal contact	11 26 59·5	2 12 38·2				"
187						Internal contact	10 48 8·6	1 33 47·3				200
188	Aug. 23	10 53	T.	III	Tr. E.	About bisected	10 51 34·1	1 37 12·8				"
189						External contact	10 56 17·1	1 41 55·8	1 44			"

Remarks.

Ref. No.
162, 163, 164 } Planet very tremulous and ill defined.
165, 166, 167 } Well defined; limb slightly indented when shadow first seen. The internal contact (167) considered good.
168, 169 } Well defined; internal contact lost; came too late to instrument.
170, 171, 172 } Not well defined; external contact (170) and bisection (171) fair, and internal contact (172) very good.
173, 174 } First seen as a mere speck; very good observation; well defined.
175 Late.

Ref. No.
177 Very good; well defined.
178, 179, 180 } Very good; well defined.
181, 182, 183 } Very good; well defined.
184, 185, 186 } Not good; definition wretched.
187, 188, 189 } Satellite steady, but limb of planet rather tremulous.

Ref. No.	Date and Time.	Observer.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding G.M.T.	Time by Nautical Almanac.	Apparent Error of Nautical Almanac.	Power.
					h m s	h m s	h m s	m s	
190				Limb indented	7 47 41·5	22 33 20·2	22 34		200
191	Aug. 25 7 50	T.	I Sh. I.	Atmt. bisected	7 48 32·5	22 34 11·2			"
192				Internal contact	7 50 14·5	22 35 53·2			"
193				Internal contact	9 57 15·7	0 42 54·4			"
194	10 0	T.	I Sh. E.	Atmt. bisected	9 58 36·7	0 44 15·4			"
195				Limb complete	10 0 11·2	0 45 49·9	0 50		"
196	Aug. 26 7 23	T.	I Pr. E.	First seen	7 21 36·1	22 7 14·8	22 7 46	+0 31·2	"
197				Full blaze	7 25 10·6	22 10 49·3			"
198	Aug. 29 8 0	T.	IV Pr. D.				22 37 58		"
199				External contact	8 29 2·1	23 14 40·8			"
200	8 32	R.	II Oc. D.	Atmt. bisected	8 31 6·1	23 16 44·8			"
201				Internal contact	8 33 59·9	23 19 38·6	23 18		"
202				External contact	7 53 8·4	22 38 47·1			"
203	Oct. 2 7 55	T.	I Oc. D.	Atmt bisection	7 54 53·4	22 40 32·1			"
204				Disappearance	7 56 51·4	22 42 30·1	22 41		"
205				External contact			23 4		125
206	Oct. 10 8 20	T.	I Sh. I.	Bisected	8 19 6·0	23 4 44·7			"
207				Internal contact	8 20 58·0	23 6 36·7			"
208	9 23	T.	I Tr. E.	Internal contact	9 20 48·8	0 6 27·5			"
209				External contact	9 24 55·8	0 10 24·5	0 8		

210	Oct. 11	7 50	R.	I	Ec. R.	First seen	7 49 31·8	22 35 10·5	22 35 22	+0 11·5	200
211						Full blaze ?	7 51 6·8	22 36 45·5			„
212	Oct. 23	9 25	T.	III	Oc. R.	First seen	9 25 20·6	0 10 59·3	0 17		„
213						About bisected	9 30 28·6	0 16 7·3			„
214						Full blaze	9 37 22·6	0 23 1·3			„
215	Nov. 4	7 47	T.	IV	Ec. D.	Half in shade	7 30 44·3	22 16 23·0			„
216						Excessively faint	7 44 14·3	22 29 53·0			„
217						Still visible	7 46 14·3	22 31 53·0			„
218						Disappeared	7 46 35·8	22 32 14·5	22 26 30	−5 44·5	„

Remarks.

Ref. No.

190 Late.

192 Good; planet unsteady.

193 Very good.

196 Very good.

198 The satellite never disappeared, but was reduced to a mere speck of light skirting margin of shadow.

199, 200, 201 Good; planet well defined and steady. The satellite disappeared behind the south dark belt, but was visible through the limb for about a minute after noted time of internal contact (201).

202, 203, 204 Not very good; planet ill defined and unsteady. The shadow of Satellite II indistinct.

205 Lost.

206, 207 Very good.

208, 209 Wretchedly defined.

210, 211 Planet very unsteady and ill defined; satellite when first seen quite distinct.

212 Supposed to be a little late. When the satellite was first seen it was sensibly separated from the limb or edge of planet, which, however, was not very well defined.

215, 216, 217, 218 Good; very steady. Planet and satellites beautifully defined; disks of latter distinctly visible. Progress of eclipse closely watched, and the instant of disappearance considered very exact.

Notes on the Physical Appearance of Jupiter etc.

1877.
June 30, 8^h. Looked at *Jupiter*. A black circular indentation on the edge of the bright belt, darker than the adjacent dark belt. The bright equatoreal belt is much broken up, and the two dark belts, especially the southern one, are marked by well defined bright streaks. The planet, however, was not very well defined.—T.

July 2, 8^h-9^h. The equatoreal bright belt appeared less dense and narrower than as seen on June 30, as though breaking up, especially near the meridian, where it was encroached upon by the dark belt to the south. The long narrow bright streak of cloud noticed on the 30th on the south dark band still visible, and certainly broader and better defined, extending from the east limb about three-quarters across the planet, tapering towards the west and having its base resting on the east edge of planet, where it merged into the bright equatoreal belt. Several remarkable darkish spots on the dark belts were visible, one near the western limb being the most marked; it was situated on the southern verge of the southern dark belt, and immediately to the east of it the adjoining southerly bright belt rose as a sharp bluff, like a cumulus cloud, as shown in the drawing; on the east side of the axis in the same belt, and to the south of the narrow bright streak before mentioned, was another dark spot; on the dark belt north of the equator, and to the east of the meridian, were several other darkish spots, of which the eastern one was the largest, and this at times appeared to extend partly across the equatoreal bright belt, giving one the idea, as it appeared and disappeared (owing probably to the variable definition or distinctness of the planet), of a flitting shadow, having apparently a pulsatory movement across the equatoreal belt. The dark belts do not appear to me to be so bright or to have the same metallic lustre as last year, being of a burnt-sienna colour and hazy. The drawing taken to-night is about $9\frac{1}{2}$ Jovian days after that taken on June 28.—T.

July 5, 9^h. Planet and satellites well defined; with powers of 300 and 600 both Mr. Ringwood and myself felt certain we saw a spot or mark near the centre of the third satellite.—T.

August 2, $8^h\ 10^m$. The definition good, but the planet had the appearance as if it was covered with a haze or fog; the clouds are not so brilliantly white, and the brown belts not so bright and lack the metallic lustre of last year. In the sketch (which is taken about 75 Jovian days after that of the 2nd July) there is shown a dark copper-coloured streak along the southern margin of the south brown belt, butting on to a bluff-headed streak of cumulus cloud which may be the same remarkable bluff head noticed on July 2. The north brown belt has a few scattered clouds in front of the shadow of the first satellite, as shown in the drawing. At $8^h\ 15^m$ it was noticed for the first time that there was a *faint* streak of cloud along the centre of the south dark band—perhaps the remnant of the narrow streak so prominent on July 2.—T. and R.

Oct. 23, $9^h\ 25^m$. At the occultation reappearance of the third satellite, when first seen, it was sensibly separated from the limb or edge of planet, which, however, was not very well defined.—T.

Total Eclipse of the Moon, February 27, 1877.

(Observer, Mr. Todd.)

Phase.	Adelaide Mean Time. h m s	Corresponding Greenwich Mean Time. h m s
Shadow first seen	14 44 17·0	5 29 56·0
„ bisecting Latronne	14 52 37·0	5 38 16·0
„ on east side of Tobias Mayer	14 55 57·0	5 41 36·0
„ bisecting Tobias Mayer	14 57 17·0	5 42 56·0
„ on west side of Tobias Mayer	14 57 26·0	5 43 5·0
„ bisecting Copernicus	15 3 25·0	5 49 4·0
„ touching east wall of Tycho	15 3 35·0	5 49 14·0
„ just over Copernicus	15 4 2·0	5 49 41·0
„ bisecting Tycho	15 4 17·0	5 49 56·0
„ bisecting Eratosthenes	15 10 52·0	5 56 31·0
„ on east wall of Archimedes	15 14 35·0	6 0 14·0
„ bisecting Archimedes	15 14 55·0	6 0 34·0
„ on west wall of Archimedes	15 15 20·0	6 0 59·0
„ on east wall of Manilius	15 17 19·0	6 2 58·0
„ bisecting Manilius	15 17 37·0	6 3 16·0
„ on west wall of Manilius	15 17 51·0	6 3 30·0
„ on east wall of Plato	15 18 2·0	6 3 41·0
„ bisecting Plato	15 18 35·0	6 4 14·0
„ on west wall of Plato	15 19 30·0	6 5 9·0
„ on east wall of Menelaus	15 20 24·0	6 6 3·0
„ bisecting Menelaus	15 20 50·0	6 6 29·0
„ on west wall of Menelaus	15 20 59·0	6 6 38·0
„ on east wall of Posidonius	15 27 32·0	6 13 11·0
„ on west wall of Posidonius	15 29 17·0	6 14 56·0
„ on east wall of Proclus	15 33 10·0	6 18 49·0
„ bisecting Proclus	15 33 35·0	6 19 14·0
„ on west wall of Proclus	15 33 53·0	6 19 32·0
„ on eastern edge of Mare Crisium	15 34 37·0	6 20 16·0
„ on western edge of Mare Crisium	15 38 57·0	6 24 36·0
Commencement of totality	15 42 4·8	6 27 43·5
About centre of totality	16 30 22·0	7 16 1·0
End of totality	17 18 13·6	8 3 52·3
East of shadow touching Damoiseau	17 18 42·0	8 4 21·0

Notes.

At 6h 18m G.M.T. the eastern limb was of a red coppery colour, which extended as far in as *Tycho* and *Copernicus*, where it gradually shaded off and changed to a deep greenish blue. At 6h 22m *Tobias Mayer* was very bright, and I could see all the diverging rays of *Tycho* as well as its prominent features and details. When totality commenced the red copper colour stretched right across the seas; about 7h 0m the outer red became more of an orange red, and the plains or seas appeared of a dark or black colour by contrast, the south pole having an orange, coppery, or rosy hue, whilst the north pole was still of a pale bluish green. At about centre of totality the south-east portion of the Moon was of a smoky orange red, extending over the whole of the Moon, leaving a fine yellow crescent round the north-west quarter, after which in the south-east portion the red became lighter and of a paler tint. At 7h 30m the yellow crescent was round the north pole, extending from west to east, the south-east portion becoming sensibly brighter; at 7h 33m the red colour was all round the south quadrant, more particularly about *Tycho*; at 7h 38m the north, east, and east-south-east limbs were of a light yellow colour, the western limb being very faint, and at 7h 48m was undiscernible.

General Description.

The total Eclipse of the Moon was observed here under most favourable circumstances. The sky was brilliantly clear, and the aspect of the heavens beautiful in the extreme.

The smoky reddish colour usually seen at lunar eclipses v well marked, but those portions of the Moon which pas through or near to the centre of the shadow were very da especially the plains or so-called seas, which appeared nea black. The red colour was not very apparent until the shad covered a considerable area of the surface, when all between a about the region of *Tycho* and *Copernicus* (over which the shad passed almost simultaneously) was of a deep smoky red—brigh near *Copernicus*; whilst towards the advancing margin of t shadow, but within it, was of a greenish blue and yellow. T centre of the Moon passed through the northern portion of shadow, and shortly before the eastern limb emerged, the wes limb and round about *Mare Crisium* was near the axis or c of the shadow and became nearly invisible; the eastern limb approached the edge of the shadow assuming the greenish y tinge of dawn, the north pole being similarly coloured, but rated by a dark gap from the illumination round the ea and south-eastern limb, and the western limb becoming al invisible, a horseshoe gulf of blackness extending inwards n half across the Moon.

Towards the end of totality, when the western limb was centre of the shadow, it became, as already stated, ne visible; I could not see it with a binocular fieldglass, ar the large telescope only by using a low power, the outlin then barely visible and the surface of *Mare Crisium* qui out. It may be remarked that at the time of central eclips was a sea horizon nearly all round, the Moon being in the of a place on the Earth, the position of which is 74° 26′ E

and 8° 13′ N. lat.; the Atlantic Ocean immediately west of Africa therefore formed the horizon or bounding surface on the west and the Pacific Ocean immediately east of Australia on the east. It is not therefore improbable that the conditions for illumination were favourable; as a matter of fact, with the exception of the obscuration of the western limb and the darkness of the large plains when near the centre of the shadow, all the prominent features of the Moon were distinctly visible, especially the bright mountain *Aristarchus*, and even the diverging rays from *Tycho* and *Copernicus* could generally be seen.

During the Eclipse a number of Occultations of neighbouring small stars occurred. One only was noted, viz. a star of about the 10th magnitude, which disappeared at the north-east limb, at $16^h\ 47^m\ 3^s{\cdot}7$ A.M.T., corresponding to $7^h\ 32^m\ 42^s{\cdot}4$ G.M.T., appearing to hang on the dark edge of the limb, which was sharply defined, for two or three seconds.

Partial Eclipse of the Sun, February 2, 1878.

(Observer, Mr. Ringwood.)

The commencement of the Eclipse was well observed here with the 8-inch Equatoreal; the first surface reflection eye-piece, with a power of 67, was used. The first contact was noted at February 2, $5^h\ 42^m\ 35^s{\cdot}0$ Adelaide mean time, corresponding to February 1, $20^h\ 28^m\ 13^s{\cdot}7$ Greenwich mean time, and may be a second or two late. No spots were visible with power 120; the Moon appeared very black by contrast, but, when the Sun was out of the field of view, it was palely illuminated by Earth-light, no lunar features being, however, discernible; weather fine, passing clouds.

Observations of the solar thermometer were not taken, on account of the passing clouds, but the shade temperature was continually watched, nothing of importance being recorded.

Transit of Mercury, May 6, 1878.

(Observer, Mr. Ringwood.)

The Egress was observed here under very favourable conditions, the definition being very fair considering the low altitude of the Sun; the 8-inch Equatoreal, with the double micrometer eye-piece and a power of 140, was used. The Adelaide mean time of internal contact at egress was noted as May 6, $19^h\ 59^m\ 32^s{\cdot}1$ and the external contact as $20^h\ 2^m\ 36^s{\cdot}5$, corresponding respectively to May 6, $10^h\ 45^m\ 10^s{\cdot}8$ and $10^h\ 48^m\ 15^s{\cdot}2$ Greenwich mean time; the egress took place at about 101° 42′ west of the north pole of the Sun.

When the planet was very close to the Sun's limb, which was

a little tremulous, the wavy surface appeared to touch the limb of the planet at times, and the time given of internal contact is when the continuity of the limb was first permanently broken and was considered very exact; there was nothing approaching the phenomenon of the black drop, nor was the planet at all distorted, though the slight boiling motion might (for the shortest possible moment) give one the idea of a fine line or hair joining the two bodies, but nothing definite or decided was seen. The planet was not in the faintest degree visible after passing off the Sun's disk. No sunspots were seen.

Meteor Showers derived from Foreign Observations: July to December. By W. F. Denning, Esq.

The showers given in the Table which follows were selected from a large number of such positions resulting from the projection of several thousand meteor-paths in the Catalogues of Heis, Weiss, Schiaparelli (1872), Zezioli, and Konkoly. They occur during the last half of the year and afford examples of well defined and active radiants, many of which will no doubt be frequently reobserved in future years. The list includes 79 of these meteor-streams, and 1,874 shooting stars were found conformable to them, giving an average of nearly 24 for each centre. The periods assigned are merely approximate. They relate simply to the dates for which the reductions were undertaken and afford no clue to the whole duration of many of the showers. Any extended references here to these newly ascertained centres are rendered unnecessary by the column of Notes affixed to them, in which many agreements and comparisons with old showers are specified; but in a few cases it seems desirable to add some particulars to what is already mentioned in the Table. The first group of reductions are for July 25–31, when the *Perseids* (No. 4) formed the most active shower and there were good contemporary radiants near θ *Persei* (No. 5) and β *Persei* (No. 3). The major shower of *Perseids* (near η *Persei*, showing a strong maximum on August 10) appears to continue certainly until the middle of September from precisely the same diverging focus as in July (compare Nos. 4 and 30 in the list). July also furnishes a good radiant close to ψ *Cassiopeiæ* which is well confirmed by Greg and Herschel and Heis, and further supported by a first magnitude stationary meteor observed by Billerbeck, at Rastenburg, on July 28, 1851, at 12°+76°, though the position is rather too far north. For August 6–12 there are some extremely well marked showers eastwards of the usual *Perseids*, several of which were already discovered by Heis in the years 1833–75, or by myself during a

number of morning observations in August 1877. The most noteworthy of these is a shower in *Camelopardus* (No. 14), near the stars *p*, *q* (of Bode), that had hitherto escaped discovery, though it is a rich and well defined radiant, which I have already referred to in the *Notices* (vol. xxxviii., p. 114), with maximum probably on about August 10. Another important system for the same epoch is given at *c Camelopardi* (No. 12), but this had already been seen by Heis and was independently found by me on the mornings of August 10–12, 1877. Mr. J. E. Clark, at York, also suspected a radiant here on August 10, 1871. The shower at 132°+77° (Nos. 10 and 21, July 25—August 12) appears to be a new position, and it is worthy of note that it falls exactly in the place of a strong October radiant. No. 22, at 74°+33°, is not quite certain as regards the exact point of radiation, which I suspect is a little further west, at 77°+32°. No. 33 is a prominent September shower well seen by me in 1877, September 4–15 A.M., at 61°+36° (15 ↓[s]), and it agrees with two old positions determined by Schiaparelli (from Zezioli's observations) and Tupman, namely :—

S. & Z.	No. 147	Sept. 8	60°+32°	Mean at 63°+36°.
T.	No. 64	Sept. 7–15	66°+40°	

Of the autumnal showers the *Orionids* (No. 47), *Taurids* I (No. 41), and *Gemellids* (No. 40) of October supply the chief examples, but these have already been well investigated by Greg. It may, however, be said of the *Orionids* that they certainly continue until November 12, for a very exact radiant, coinciding with that shower, is shown there from the meteor-paths traced by Zezioli (see No. 70). As to the *Taurids* I (No. 41), the whole duration of the major radiant would seem to be from about October 12 to the first week in December; but there are several showers lying near together here, which it is necessary to dissociate. With this object in view I recently collected and compared all the observations of this system and found that, from 38 different determinations, there are probably *four* bordering showers of *Taurids* in October—November, as follows :—

I	At 62°+21°	Oct. 12—Dec. 6	21 radiants.
II	At 56+24	Nov. 1–13	6 radiants.
III	At 53+16	Oct. 6—Nov. 9	6 radiants.
IV	At 60+ 9	Oct. 10–22	5 radiants.

I is the major radiant with a sharply defined, persistent centre enduring apparently for 7 weeks. II is at the *Pleiades* (see No. 54 in the Table) and well observed by Greg and Herschel, Tupman, and myself, and at Greenwich. III appears equally certain. It was noted by Tupman in 1869 and by Backhouse in the same year. IV requires more observations, but

Schmidt's radiant at 62°+6°, October 10–22, and Tupman's, at 58°+10°, October 13, are perhaps sufficient to establish it beyond doubt, and its continuation in November is extremely probable, for Heis, at Munster, recorded a stationary meteor on November 13, 1869, at 58°+12°, and 38 other shooting stars converged on the same centre during the first half of the month. These several showers of *Taurids* should be carefully reobserved and the distinctive features of the meteors proceeding from them noted in each case. In the mornings of October–November the *Gemellids* (No. 40) also constitute a prominent shower. Gruber, from his October 17–28 reductions, places the centre at 109°·5+25°·2, October 22–27, and Schiaparelli and Zezioli, 113°+29°, for October 21–25, 1868 (56 meteors). This radiant was traced, as far back as 1839, by Herrick. Of the remaining October showers the most conspicuous examples are at 62°+47° (No. 45), 81°+23° (No. 35), 81°+54° (No. 34, *Aurigids*), and 86°+34° (No. 50). The former was chiefly deduced from the meteors in Weiss's catalogue and is verified by several other observations. No. 35 agrees in position with the *Taurids* II (No. 72), but the dates are too widely distant to allow an inference of connection. No. 34 is one of several contemporary showers of *Aurigids*. No. 50 was strikingly well seen by Zezioli on October 21, 1868 (17½ᵐ), and this position, close to *θ Aurigæ*, is otherwise well supported as a prominent shower centre and separate from No. 39 at 78°+33°. For the first half of November the Table contains several good instances of morning showers, now satisfactorily determined for the first time. There is a rich stream at 142°+29°, near *κ–μ Leonis* (No. 61), accurately indicated by 31 paths and quite distinct to the *Leonids*. Schmidt saw this radiant at 140°+23° on October 19–27 and on the mornings of October 15–18, 1877, I traced a shower of swift, streak-leaving meteors (one of them stationary) from an exact centre at 140°+28°. The members of this stream have no doubt been confused hitherto with the *Leonids*, for the positions are close together and the phenomenon of streaks is a characteristic of the members of both systems. Schmidt's position for the new shower is about 5° too far south of the true centre, and it is rather remarkable that for December 9–12 there is also a good radiant at 143°+28°, which, agreeing so closely in place, seems merely a continuation of it. The other November showers given in the list are also very satisfactory and confirmed in nearly every case by Zezioli, Tupman, or myself during numerous morning watches in that month.

The *Taurids* II (No. 72) of December, with a strong maximum on about the 6th, had long escaped observation, appearing as they did at a time when the *Geminids* occupied attention, and there is little doubt that many of these *Taurids* were attributed to the wrong stream. A stationary meteor belonging to it was recorded by Bartel, at Brünn, on December 11, 1869, at 82°·9+22°·9, and this position, close to *ζ Tauri*, has been amply

confirmed by Greg and others. The shower in *Camelopardus* (No. 79), at 110°+70°, is a new one, but we require further observations before it can be safely regarded as established beyond doubt. The December showers, Nos. 73 to 77, in *Cancer*, *Leo*, and *Ursa*, agree very exactly with showers deduced for November (compare Nos. 62, 58, 63, 61, and 57); in fact it would seem, from a careful inspection of the observations, that these several radiant centres are in continuous operation from the middle of October to the middle of December! Yet such long duration is inadmissible on theoretical grounds, and to obviate the difficulty we have to assume a succession of distinct showers having, curiously enough, the same points of departure though no real connection exists between them. Whether the effects of planetary perturbations on these attenuated meteor streams is such as to diffuse them over a considerable epoch without sensibly altering the radiant points has yet to be ascertained; meanwhile observers will state the legitimate result of their labours apart from theoretical considerations, however incompatible they may at first appear.

A Synopsis of Old and New Meteor Showers (occurring during the last half of the year), derived from the Meteor Paths recorded in the Catalogues of Heis, Weiss, Zezioli, Schiaparelli, and Konkoly.

Ref. No.	Period of Shower.	Radiant Point. R.A.	Radiant Point. Dec.	No. of ↓s	Observer or Authority.	Name of Shower or Approximate Star (Bode).	Remarks and Comparisons with previous Observations.
		°	°				
1	July 25 31 and Aug. 13	15	+70	35	H.W.Z. & K.	ψ Cassiopeiæ	12+70, July 7–Aug. 4, G. & H.; 15+70, July 28–29, H. Well seen in 1878, at 12+70, July 26–Aug. 2 (16 ↓s), D. *See* No. 56.
2	July 25 31	67	+66	14	H.W.Z. & K.	*c* Camelopardi	Beginning of No. 12; requires verification.
3	July 25 31 and Aug. 13	41	+40	28	H.W.Z. & K.	β Persei	38+38, July 31, 1856, Heis (stationary meteor). *See* No. 45.
4	July 25 31	45	+57	31	H.W.Z. & K.	Perseïds	Early members of the great August shower, with max. on 10th. *See* No. 30. Very few seen before Aug. 7, 1878, D.
5	July 25 31 and Aug. 13	32	+51	35	H.W.Z. & K.	θ Persei	37+48, July 19–Aug. 2, H.; 35+47, July, D. *See* No. 44. A very fine shower (63 ↓s) July 21–Aug. 1, 1878, at 32+53; maximum, July 30–Aug. 1, D.
6	July 25 31	23	+41	15	H.W.Z. & K.	γ Andromedæ	New shower. 23+41, July 29–Aug. 1, 1878, D. Compare with No. 32.
7	July 25 31	25	+57	23	H.W.Z. & K.	Cassiopeïds	Radiant diffuse and uncertain. 24+50, July 19–31, H.
8	July 25 31	13	+52	18	H.W.Z. & K.	Cassiopeïds	7+50, July, S. & Z.; 6+53, July, D. Seen also by Italian observers, 1872. 12+52, July 21–Aug. 1, 1878, D.
9	July 25–31	48	+73	14	H.W.Z. & K.	Custos	Beginning of No. 16.
10	July 25 31	130	+77	11	H.W.Z. & K.	29 Ursæ Majoris	Beginning of No. 21.
11	July 25–31	63	+50	10	H.W.Z. & K.	μ Persei	Beginning of No. 15.

These several showers require more observation in July. They are already well established for Aug. 6–12.

13	Aug. 6–12	61+39	59	S.H.W. & K.	ϵ Persei	64+39, Aug. 11–19, H.; 61+43, Aug. 10, Parnisetti. *See* No. 49.
14	Aug. 6–13	96+71	106	S.H.W. & K.	p, q Camelopardi	A new and rich shower; the chief rad. E. of *Perseus*, Aug. 6–12. Slightly seen by D., July 30–Aug. 1, 1878. Meteors rather slow.
15	Aug. 6–12	61+48	59	S.H.W. & K.	μ Persei	61+48, Aug. 3–16, 1877, D.; 56+47, Aug. 3–11, Schmidt. *See* No. 45. The fireball of Aug. 11, 1876, had a radiant at 60+51 (A.S.H.)
16	Aug. 6–12	51+74	62	S.H.W. & K.	Custos	51+75, Aug. 6–12, H.; 50+75, Sept., G. & H. Compare No. 29. Seen also by D., July 26–31, 1878, at same point.
17	Aug. 6–12	78+56	59	S.H.W. & K.	δ Aurigæ	77+54, Aug. 11, 69, W.; early *Aurigids*. *See* No. 34. Stationary meteor seen by D. at 77+54, July 20, 1878.
18	Aug. 6–12	76+45	43	S.H.W. & K.	α Aurigæ	75+45, Aug. 29, 1870, T. Well defined radiant; 3 meteors stationary.
19	Aug. 6–12	50+47	42	S.H.W. & K.	α Persei	50+48, Aug. 3–12, Schmidt; 48+48, Aug. 6, 1869, T.
20	Aug. 6–12	92+57	42	S.H.W. & K.	δ Aurigæ	94+62, Aug., G. & H. Requires more observations.
21	Aug. 6–12	134+77	30	S.H.W. & K.	29 Ursæ Majoris	New shower. ? beginning of Heis's N_{18}, 130+84, Sept. Supported by 2 meteors, almost stationary, in July, on 21st, 1878, D.; and 26th, Strasser. *See* No. 10.
22	Aug. 6–12	74+33	28	S.H.W. & K.	ϕ Aurigæ	70+31, Aug. 29, 1870, T.; 70+32, Sept., Schmidt. *See* No. 39.
23	Aug. 6–12	104+34	13	S.H.W. & K.	θ Geminorum	110+32, Aug. 20–25, 1871, T. (suspected). Visible just before sunrise.
24	Aug. 6–12	99+45	17	S.H.W. & K.	Telescopium	A new radiant; distinct from the preceding. *See* No. 38.
25	Aug. 6–12	45+33	18	S.H.W. & K.	Musca	41+34, Aug. 10, S.; and Aug. 4, T. *See* No. 48.
26	Aug. 6–12	76+74	20	S.H.W. & K.	Camelopardus	Perhaps connected with No. 14: requires confirmation.

Ref. No.	Period of Shower.	Radiant Point. R.A. °	Dec. °	No. of ↓s	Observer or Authority.	Name of Shower or Approximate Star (Bode).	Remarks and Comparisons with previous Observations.
27	Aug. 6–12	52	+20	14	S.H.W. & K.	η Tauri	50+20, Aug.–Sept., 1871, Corder; 48+19, Aug. 10, Denza.
28	Aug. 6–12	87	+34	14	S.H.W. & K.	θ Aurigæ	A new Aug. shower; requires more observations. *See* No. 50.
29	Aug. 13	59	+70	10	H.W.K. & Z.	Camelopardus	Probably the same as No. 16. 59+70, Aug. 8–12, H.
30	Aug. 24–Sept. 14	45	+57	23	Z. & S.	Perseids	Late members of the August shower; radiant well defined.
31	Sept. 5–12	335	+47	9	Z.	Lacertids	334+48, Aug. 23, 1870, T.; same rad. as July–Aug. *Lacertids*.
32	Sept. 5–12	22	+45	13	Z.	γ Andromedæ	25+46, Aug.–Sept., 1877, D.; requires more observations.
33	Sept. 5–12	60	+37	9	Z.	ε Persei	No. 13 continued. A very good shower; seen by Z., T., & D.
34	Sept. 5–Nov. 12	81	+54	29	Z. & W.	δ Aurigæ	A long enduring shower, with diffused rad.; also Dec. 9–12, 80+50 (28 ↓s), D. and others.
35	Sept. 5–12 and Oct. 12–31	81	+23	30	Z. & W.	ζ Tauri	84+21, S. & Z., Oct. 13–21; perhaps two showers close together here? Active shower, 78+23, Sept. 8–10, 1869, T. *See* No. 72.
36	Sept. 8–Oct.	155	+41	13	Z.	μ Ursæ Majoris	154·5+41·5, Sept. 15–Oct. 18, 1877, D.; a good A.M. shower.
37	Oct. 12–13	5	+53	9	Z.	ζ Cassiopeiæ	5+53, Oct. 22–28, Schmidt; 5+55, October, G. & H.
38	Oct. 12–Nov. 7	98	+44	20	Z.	Telescopium	98+45, Nov. 1877, D.; also at 105+52, in October.
39	Oct. 12–31	78	+33	14	Z. & W.	φ Aurigæ	Sharply defined and exact; seen also by T., Oct. 13, 1869, and D., Oct. 8, 1877.
40	Oct. 12–Nov. 12	108	+24	50	Z. & W.	Gemellids	Rich shower seen by many observers; 105+27 (G., 1876).
41	Oct. 12–Nov. 12	62	+21	65	Z. & W.	Taurids I.	62+21, fireball of Nov. 23, 1877, T. A long enduring, rich, and well defined shower. N. of α *Tauri*.
42	Oct. 20–31	40	+21	18	W.	ε Arietis	43+22, Oct. 31–Nov. 1, 1877 (13 ↓s), D.; distinct from No. 48 *Muscids*.

43	Oct. 20–31	25+44	12	W.	γ Andromedæ	24+42, Oct. 17–31, 83 meteors, H. *See* No. 32.
44	Oct. 20–31	34+52	12	W.	θ Persei	32+50, Oct. 8, 1877, D.; exact and certain shower; meteors slow.
45	Oct. 20–31	62+47	31	Z. & W.	μ Persei	Strong radiant; seen at same point by D. (1877) and Italians (1872).
46	Oct. 20–31	40+40	22	W.	β Persei	37+38, Oct. 17–31, H. Compare with No. 3.
47	Oct. 20–31	92+18	64	Z. & W.	Orionids	Rich shower with strong max., Oct. 18–20. *See* No. 70.
48	Oct. 20–Nov. 7	42+31	24	Z. & W.	Muscids	39+30, Oct. 19, Gruber; 46+35, Aug. 22–Oct. 20, Greg.
49	Oct. 20–Nov. 12	62+37	21	Z. & W.	ϵ Persei	62+37, Oct.–Nov., Italian observations, 1872; 62+37, fireball, Nov. 6, 1869. (A.S.H.)
50	Oct. 21—Nov. 9–12	86+34	26	Z.	θ Aurigæ	Strong shower, Oct. 21, 1868 (Z.); 86+36, Nov. 7–10, 1876, Corder.
51	Oct. 19–27	300+55	10	W.	ψ Cygni	307+53, Nov. 1–13, Schmidt; not quite certain. A shower of bright meteors at 306+54 also on Sept. 1, D. and others.
52	Nov.	173+12	10	W.	β Leonis	A new radiant visible just before sunrise; requires further obs.
53	Nov. 1–7	120+40	9	Z.	Telescopium	125+40, Nov. 12, 1877, D.; exact and certain.
54	Nov. 1–7	56+23	11	Z.	η Tauri	56+24, Nov. 1–10, G. & H. & T. Distinct from *Taurids* I. (41).
55	Nov. 1–7	110+61	9	Z.	h Lyncis	Not certainly established. 111+65, Nov. 30, 1867, Z.
56	Nov. 1–7	15+74	7	Z.	f Cassiopeiæ	11+70, Oct. 8–14, 1877, D.; requires further watching.
57	Nov. 1–15	133+48	26	Z.W. & T.	ι, κ Ursæ Majoris	130+48, Oct. 21, S. & Z.; a well known shower; seen by many observers.
58	Nov. 1–15	149+38	23	Z.W. & T.	λ, μ Ursæ Majoris	142+36, Nov. 10–Dec. 9, S. & Z.; radiant not well defined.
59	Nov. 1–15	130+31	15	Z.W. & T.	ρ Cancri	133+31, Oct. 28–Nov. 13, 1877, D.; seen also by Schmidt in December.

Ref. No.	Period of Shower.	Radiant Point. R.A. ° Dec. °	No. of ↓s	Observer or Authority.	Name of Shower or Approximate Star (Bode).	Remarks and Comparisons with previous Observations.
60	Nov. 1–15	147+22	26	Z.W. & T.	Leonids	A few stray members of the great periodical shower.
61	Nov. 1–15	142+29	31	Z.W. & T.	κ Leonis	140+28, Oct. 15–18, 1877, D.; Schmidt also 140+23, Oct. 19–27. *See* No. 76.
62	Nov. 1–15	132+20	17	Z.W. & T.	δ Cancri	133+21, Oct. 15–18, 1877, D.; a well marked shower. *See* No. 73.
63	Nov. 1–15	122+14	13	Z.W. & T.	ζ Cancri	120+15, Oct. 15–18, 1877, D.; radiant sharply defined. A shower here also on Sept. 25, 1878, D. *See* No. 75.
64	Nov. 1–15	144+52	14	Z.W. & T.	θ Ursæ Majoris	A shower also strongly suspected at 145+43.
65	Nov. 1–15	120+23	16	Z.W. & T.	μ Cancri	Possibly a new radiant; requires further investigation.
66	Nov. 1–15	175+32	8	Z.W. & T.	Coma Berenices	178+34, Oct. 16–17, 1877, D.; new shower in *Coma* just before daybreak.
67	Nov. 1–15	134+ 8	12	Z.W. & T.	ζ Hydræ	134+6, December, G. & H.; radiant not very certain.
68	Nov. 1–15	142+17	8	Z.W. & T.	ο Leonis	146+16, December, Schmidt; requires further watching.
69	Nov. 1–15	140+62	13	Z.W. & T.	τ Ursæ Majoris	140+65, Nov. 8–Dec. 13, D.; stationary meteor seen by Billerbeck, 145+61, Nov. 13, 1852.
70	Nov. 9–12	94+18	8	Z.	Orionids	Compare with No. 47. Late members of the October periodical shower. Radiant sharply defined.
71	Dec. 7–13	200+67	9	W.	α Draconis	209+67, Nov. 25–Dec. 20, Corder, Denza, and D. A shower from this point also in Jan. and Feb.
72	Dec. 7–13	83+23	27	W.	Taurids II.	A marked shower seen by D., Corder, and Sawyer, and confirmed by Greg; maximum Dec. 6.
73	Dec. 9–12	133+19	10	W.Z. & H.	δ Cancri	Continuation of No. 62. Comet of 1680 ☄, 133+22, Dec. 27. 129+19, Dec. 21, 1876, D.

74	Dec. 9–12	152+43	16	W.Z. & H.	λ, μ Ursæ Majoris	149+45, Dec. 9–13, S. & Z. Compare Nos. 36 and 58.
75	Dec. 9–12	120+15	11	W.Z. & H.	ζ Cancri	*See* No. 63. These three showers, with the two preceding, apparently begin early in October and endure until about the middle of December. Radiation is sustained from the same points.
76	Dec. 9–12	143+28	10	W.Z. & H.	χ Leonis	*See* No. 61.
77	Dec. 9–12	134+50	11	W.Z. & H.	ι–κ Ursæ Maj.	*See* No. 57.
78	Dec. 9–12	178+46	10	W.Z. & H.	χ Ursæ Maj.	180+53, Dec. 12, S. & Z. A well defined shower.
79	Jan. 6–Feb. 16	110+70	26	Z.S. & H.	Camelopardus	Seen chiefly by Zezioli, Jan. 28. Requires further proof.

The abbreviations are—H., Heis (Observations from 1833–75; W., Weiss (Austrian Observations, 1867–74); Z., Zezioli (Observations at Bergamo, in Italy, 1867–70); S., Schiaparelli (Italian Observations, 1872); K., Konkoly (Hungarian Observations, 1871–76); G. & H. Greg and Herschel (British Association Observations, 1850–74); T., Tupman (Observations in the Mediterranean, 1869–71); and D., Denning (Observations at Bristol, 1876–78).

Account of additional Buildings and of Proceedings at the Oxford University Observatory. By Prof. C. Pritchard.

In the *Monthly Notices* for December 1873 and December 1875 I have described the buildings and Astronomical Instruments which the University of Oxford has provided for the use of the Professor of Astronomy. The results that have so far been derived therefrom may be understood from an inspection of the first issue of the *Astronomical Observations* and other astronomical work completed in the new Observatory during the first two years of its existence. Copies of this publication have been presented to the Society and to similar institutions.

At present we are earnestly engaged in measuring and reducing the measures of the Lunar Photographs which have been taken with all possible regularity for now nearly three years, with the De la Rue mirror of 13 inches aperture. The measures are made with a large but very delicate measuring engine, devised by Mr. De la Rue and executed with great precision by Mr. Simms. With care it is capable of measuring angular distances on the lunar photographs equivalent to one-tenth of a second of arc. Certain elaborate measures, and their subsequent numerical reductions, from their remarkable consistency of result, inspire me with the hope that we may in due time succeed in ascertaining the existence and approximate amount of the lunar physical libration. I propose, at the next meeting of the Society, to lay before them a short account of these preliminary measures and reductions; and I think they will be sufficient to show that careful photography is very effectively applicable to certain classes of astronomical investigations.

We have also made one complete set of measures of 40 stars in the *Pleiades* with my new duplex micrometer: this work is now in process of repetition, partly with the view of practically testing how far this instrument is capable of doing such work as is usually assigned to the heliometer; and partly with the view of ascertaining if any relative displacements in this group of stars have occurred since Bessel's celebrated measures of the *Pleiades* with the Königsberg heliometer in 1841. A general description of the principles and construction of this instrument will accompany the communication to the Society referred to in the last paragraph.

This evening I have contributed to the Society a few measures of the coordinates of Tempel's periodical comet at its apparition in July last: they were taken with the Grubb refractor of 12¼ inches aperture.

Such, then, is a general and rapid account of the researches completed and undertaken at the University Observatory since its erection three years ago.

My present object, however, is to acquaint the Society with another act of thoughtful liberality on the part of the University

towards the prosecution of the study of astronomy in Oxford. The buildings containing the large Grubb refractor and the De la Rue reflector, and comprising also two computing rooms, partly occupied by the huge piers supporting the instruments, contained no provision for the Professor's lectures to the University students. This want has now been very effectively supplied by the building, under the auspices of Mr. Charles Barry, of a convenient library and a well contrived lecture room, sufficient to satisfy all reasonable requirements. The dimensions of the lecture room are 40 feet by 27 feet, with a height of 18 feet. It is most amply lighted by five large windows having a northern aspect. The rooms and the entire Observatory are now warmed with hot water pipes; and the large instruments are effectually protected from the deposition of dew by the admission of warm air, at will, through large trapdoors in the ceilings of the rooms below; the trapdoors being provided with strong combings ot latticework. With this exception, there is little or no novelty in the arrangements thus described.

But it occurred to me, while designing the large lecture room, that its roof might possibly be utilised for the formation of an out-of-doors or open-air Observatory, provided with suitable instruments for the instruction of the students, and for other purposes of original work. This design has been successfully carried out. The roof of the lecture room is flat and is covered with lead. Over this lead is placed a strong floor of battens with interstices between them for the passage of rain water. A somewhat high parapet extends on all sides above the roof, for the protection of persons upon the latter. Into the walls of the room have been inserted the ends of two very strong flitched beams with iron plates between them, and not touching the roof of the building. These two flitched beams are bolted together, and on them are placed massive stone slabs affording platforms for the telescopes to be placed upon them. These telescopes at present are two; viz. a refractor by Cooke of $4\frac{1}{4}$ inches aperture, and an exquisite reflector by With of $10\frac{1}{4}$ inches aperture. Both these instruments are practically free from tremor, even when many persons are assembled on the battened floor, and one or two standing on the beams. This is a degree of success in the mounting of instruments which I hardly ventured to anticipate: but so it is.

A third telescope of $3\frac{1}{2}$ inches aperture is placed on the leaded roof, but not in contact with the battened floor; this also admits of use without any tremor sufficient to annoy. A transparent drum of 2 feet diameter, revolving on an axis pointing to the pole, and containing the allineations of the principal stars, and lighted by a lamp within, completes the astronomical equipment of this somewhat novel out-of-doors Observatory. I ought, however, to remark that all these instruments are provided with light and easily removable housings to protect them from the weather. The roof also is well provided with gaslights for any temporary purpose.

Besides these astronomical instruments, there is placed
the parapet an efficient form of Campbell's globular lens f
measuring and recording the duration, and to a considerable e
tent the comparative intensity, of sunshine during each da
This (to me, at least) interesting instrument I have cover
with a thin cylindrical glass shade; and close to it is
radiation thermometer with a blackened bulb in vacu
The instrument, *in this protected form of it*, is, I believe,
novelty not without its value; and hitherto its action has be
admirable, inasmuch as it is very easy to read at a glance t
duration of even any fitful sunshine during a succession
showers, within intervals of three or four minutes of time. I
the side of it I have placed a Sun Spectroscope, for the observi
of the "*Rain Bands*," together with a new and effective form
Daniells's hygrometer, designed by Mr. Bouillard, for comparis
with the spectroscope in the forecasting of rain. Up to the pr
sent time the indications have been much to the advantage of t
spectroscope. I can hardly doubt that these details of attempts
excite at least the curiosity of a large and important class
University students in subjects more or less astronomical, t
gether with the account of the proceedings of our new Astron
mical Institution at Oxford, will not be without their interest
many members of the Society.

I will only add that the Board of Visitors, at the head
which is the Vice-Chancellor, have sent in a recommendation
the University Commission for the furnishing of such funds a
instruments as are necessary for the efficient maintenance of t
Observatory. They also recommend the founding of a few astr
nomical studentships for the encouragement of the study of c
science.

Oxford University Observatory,
Nov. 1878.

On the Spectrum of the New Star in Cygnus.

By T. W. Backhouse, Esq.

Soon after the appearance of the new star in *Cygnus*, and
various times since, I made observations on its spectrum w
one of Browning's miniature spectroscopes on a Cooke's refrac
of 4¼ inches aperture. With such small instruments accur
measurements have not been possible; and those I made must
taken for what they are worth.

I compared the spectrum of the star with those of vacu
tubes, of sparks in air, and of a Bunsen's burner; and from th
observations I have calculated the positions of the bright lines
Huggins' scale. These are shown in Table I.; and the weigh
attach to each observation is also given.

In Table II., Column A, these positions are reduced to wa
engths. My drawings of the spectrum show that these resu
cannot be all correct, and in Column B are given what I jud
therefrom to be more accurate positions, and also those of t

lines that I only suspected. Column C gives Cornu's positions of the lines,* so far as they can be identified with mine; Column D gives Dr. Vogel's;† Column E, Dr. Copeland's, Jan. 1877;‡ and Column F, Lord Lindsay's, Sept. 1877. In Vogel's drawing of Dec. 8, 1876, all my lines are shown, except κ, besides a large number of others. The chief differences between my drawings and his of corresponding periods are the brightness in mine of δ and β and the feebleness of the diffused light next α towards β. Copeland's 456 and 414 are not certainly identified with mine.

Table III. gives the estimated relative brightness of the lines, that of γ being throughout taken as 1. A line given as ·5 is therefore one which I estimate to be half the brightness of γ, approximately. A query signifies a line merely suspected.

On July 24, 1877, γ was the only line visible, but there was much moonlight. On Aug. 8 I was almost sure of the existence of one line less refrangible than γ, and suspected another. On Nov 6 γ was the only line; but on the 29th I again suspected a line or two towards the red. On Dec. 7 γ was the only line.

I will add the following notes on the continuous spectrum.

1876, Dec. 28. Brightest from α to ϵ, especially about β and from γ to ϵ; also for a short distance after ζ, and again before η.

1877. On Feb. 12 I remarked that it had throughout remained brightest in much the same region, but that it was perhaps a little fainter in comparison with the bright lines.

March 14. Continuous spectrum very slight; it lies mostly on the least refrangible side of γ.

Aug. 8 and Nov. 6. A portion still suspected on the red side of γ.

Nov. 29 and Dec. 7. A portion suspected on each side of γ.

As the latter observations were made with the slit open to its widest extent, it is quite possible that some minute star may have been included in the field and so caused a continuous spectrum. It is undoubtedly the case that almost the whole of the light of the new star was then contained in the one bright line γ.

On February 2, 1878, I observed the spectrum by the method of simply placing a prism in front of the eye-piece of the telescope, when it appeared exactly like a star without the prism.

When I last looked for the star, on May 17, I found it was still fading, it being not certainly visible in the telescope; there were, however, both moonlight and twilight.

It must be understood that, though throughout this paper I have spoken of bright "lines" in the spectrum, they really appeared as points with my method of observing them—focusing the star on the spectroscope.

As regards the colour of the star, on December 22, 1876, it appeared white, but the observation was not favourably made. From December 27 to January 8 it was orange, at one time a deeper colour than 75 *Cygni*. On January 20 it appeared yellowish, but was getting too faint for its colour to be well distinguished.

* *Nature*, vol. xv., p. 158. † *Ibid*, vol. xvi., p. 400.
‡ *Ibid*, vol. xvi., p. 401.

TABLE I.—*Positions of the Bright Lines on Huggins' Scale.*

1876.	α	Weig.	β	Weight.	θ	Weight.	γ	Weight.	δ	Weight.	ε	Weight.	ζ	Weight.	η	Weight.
Dec. 28	1005	5	1430	5			1750	10	1900	10	2050	10	2450	10	3370	5
,,	1060	5	1550	5	1710	5	1940	5	2085	5	2230	5	2640	5		
,,	1015	15	1550	15	1710	15	1950	15	2105	15	2260	15	2660	15		
1877.																
Jan. 8							1820	15			2075	15	2520	15		
19							2060	3								
20							2060	25			2325	25				
,,							1880	10								
25							1855	12								
Feb. 12	1140	8					1980	5			2165	6	2415	5	3425	5
,,							1940	10			2155	6	2595	10		
Mar. 14							2015	12								
,,							1995	12								
,,							2015	8								
,,	930	3														
15	1210	2														
,,	1045	5					1885	8								
,,							1765	8								
,,							1911	15								
May 15							1937	15								
,,							2015	10								
July 24							1934	20								
Dec. 7							1967	20								
Average	1049	43	1526	25	1710	20	1937	238	2033	30	2204	82	2557	60	3397	10

TABLE II.

Wave-lengths of the Bright Lines.

Line.	A. By comparison with other spectra. Backhouse.	B. By drawings. Backhouse.	C. Cornu.	D. Vogel.	E. Copeland.	F. Lindsay.
α	5831	5831	δ, 588	580	•	
?ι		?5630				
β	5333	5315	γ, 531	527		
θ	5183	5210	β, 517	514		
γ	5022	5022	ζ, 500	499	504	4986
δ	4960	4943				
ε	4858	4858	η, 483	Hβ, (486)	486	
ζ	4679	4660		467	?456	
?κ		?4590				
η	4367	4367	ε, 435	Hγ, (434)	?414	

TABLE III.

Relative Brightness of the Lines.

Line.	1876. Dec. 27.	Dec. 28.	Dec. 30.	1877. Jan. 2.	Jan. 8.	Jan. 17.	Jan. 19.	Feb. 7.	Feb. 14.	Mar. 14.	May 15.
α	·8	1·0	·8—	·45	·2	·17	·15	·12	?·1	·15	·1
?ι		?·1					?·02				
β	1·0	1·0	·8—	·4	·2	·15	·1	·12	?·1	·05	
θ		·5		·5							
γ	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0
δ	1·3	1·0	·8—	·6			?·02				
ε	2·5	2·0	2·0	1·7	·5	·6	·5	·3	·25	·25	·08
ζ	·8	·5	·8	·45	·2	·2	·17	·15	·15	·15	·06
?κ		?·1					?·02				
η	·2	·1		·25			·02	·08	?·1	·05	

Sunderland, June 3, 1870.

Measures of the Great B Line in the Spectrum of a High Sun.

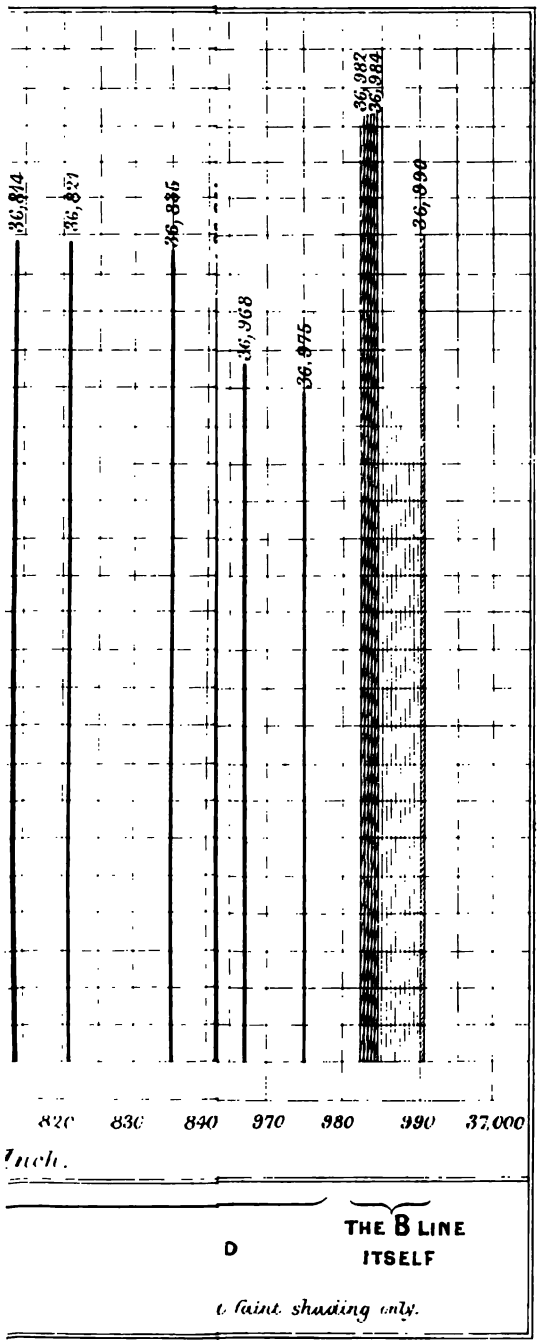
By Prof. Piazzi Smyth, Astronomer Royal for Scotland.

It is not known, I believe, as yet, by any direct experiment, to what chemical element, or elements, the B line in the solar spectrum is to be attributed. In its main part, if not also in its entirety, it must be of telluric, rather than solar, origin—because it is one of those lines which darken egregiously, and thicken also, when the C line of solar hydrogen does not, as the setting Sun approaches the horizon; a duplicate fact observed by me so far back as 1856, on the peak of Teneriffe. But it is more the *beauty* of the B line which has been of late dwelt on by observers possessing very powerful spectroscopes. "The most beautiful line in the whole solar spectrum" is a remark in one of his many optical papers by the accomplished Mr. Rutherfurd, of New York, probably the greatest master of line drawing and most consummate judge of geometrical symmetry and mechanical perfection in the whole world.

In what, then, does the alleged beauty of the said B line consist? I presume the answer will greatly depend on the degree of telluric development under which the line may have been viewed by each observer; always assuming that everyone means equally to express by "the line B" the whole congeries of lines forming both the attached band and the preliminary band to the actual line B; which, moreover, even in itself, is anything but a simple, single, line when in presence of still more penetrating examination.

Generally, however, and to all inhabitants of northern countries at least, where the Sun can never be observed very near the zenith, and therefore not through a zenithal *minimum* thickness of the Earth's atmosphere, the almost proverbial beauty of the great B line must consist in the rhythmical arrangement of the powerful lines forming the preliminary band to B and its attached band of finer, closer-set lines, or even linelets. Forcible, dark lines the former are, clean edged, well defined, no one of them exactly like another, either in thickness, or depth of colour, or distance from its neighbour on either side, and yet the whole forming a harmonious group, from which not one element could be taken away, and to which not one could be added, without introducing a discord and spoiling the entire system.

Such, I am quite aware, is not the manner of representation of the preliminary band of B, either by a high or a low Sun, in the Royal Society's second plate of one of such a spectrum as seen in the Rothamsted [illegible] like a uniform force of thin wires in one case, and of thick ones in another. Nor is it like the unfortunate [illegible] which [illegible] resulted to Kirchoff's original [illegible] from having at any passed through [illegible] adopting that method [illegible] the imper-



IN A HIGH

ved higher in

P. S. del.

fections of their first stone for black ink printing by other stones printing tints only, and seldom registering exactly. But my description does come very close to the admirable reproduction of B in Angstrom's normal solar spectrum; printed from stone also, but at one printing only, and from lines incised through a thin gum coating on the prepared surface of the stone, or rather into its very substance, and therefore as certain and secure as if engraved on a copper plate.

I had often admired the beauty of symmetry in Angstrom's "great B," and had seen something very like it when observing the solar spectrum last year at Cintra, merely with my aurora spectroscope; but what I saw then by no means prepared me for the transcending beauty of what beamed forth this year, with a better prepared solar spectroscope, and in the highest Sun which mid-day, at the summer solstice, could offer in Lisbon.

And pray what formed the beauty of the B line, then and there, do you ask? Unwilling to trust my own eyes alone, I asked my Wife to look into the telescope, and immediately came the exclamation, "Oh! the beautiful double lines!" Exactly so! each of the usually seen thick lines was now a double line, or rather showed two lines; so perfectly free from any filling up, even with the faintest haze, was the space between the components of any and every pair; while every line was so almost infinitely fine, but at the same time infinitely sharp, clear, and well defined on either side, and such perfect order and symmetry pervaded the whole arrangement, that it was a case *par excellence* of science and art combined.

With prism dispersions from 28 to 50 degrees between A and H, and a magnifying power of 20 on the telescope of inspection, the above features were abundantly distinct; and still further detail could, by careful attention, be made out in the closer system of the *attached* band of B.

This has always been rather a difficult subject. Wherefore in Brewster and Gladstone's enlarged view of B in the *Philosophical Transactions* for 1860, they show an anomalously large opening between the B line and its now so-called "attached band." While Angstrom, usually so trustworthy, and so powerful too at the red end of the spectrum, merely has a telluric shading, all but vanishing for a high Sun, and four single separate lines, of apparently foreign, though perhaps solar, character, in place of the attached band of B.

My published view of that band last year was confessedly imperfect and approximate only; but this year, while again establishing that there is such a band existing even in an almost zenith Sun, the earlier lines composing it were found to be a set of exquisitely close doubles, every one of them. While amongst the later ones were found some stronger single lines, partly confirmatory of Angstrom, and partly, from their greater distance asunder, confirming, or rather apologising for, the actual opening in Brewster and Gladstone's view.

Lastly, we come to the very B line itself; black and thick enough for anything in most plates published hitherto; but, in the highest Sun of Lisbon, shown to consist of a wonderful grouping of the finest possible lines. First a bundle of half a dozen or more, closely packed together into a shape like a Roman lictor's rod, so that, with smaller dispersion or worse definition, it would certainly be set down as a single, though clumsy and coarse, line; then a pale space, just indicating its composition of the feeblest, closest, and most uniform lines possible; and then a stronger line terminating the same space, and finishing off this marvellous and most compound arrangement spoken of so familiarly hitherto as merely "the great B line."

Seeing that the group—constellation almost—has such a decided and well marked physiognomy, and as the harmony and symmetry pervading all its lines of construction—except perhaps the few single lines seen in, or projected upon, the attached band—show it to be dependent on one element or elementary combination, and not to be the result of a chance coming together of stray lines from all sorts of alien elements scattered through the rest of the spectrum, I append both a record of my micrometer measures, though far from positively accurate, and a graphical representation; fervently hoping that by aid of it, notwithstanding its manifold imperfections, the chemists may one day succeed in finding a substance which, under *some* temperature or pressure, may present just such a picture, but in bright lines; and then there will be no sort of doubt at all, as to "what makes the great B line."

November 4, 1878.

Postscript.—(Nov. 22, 1878.)—Having received from Paris this morning a copy of the Second Edition of the late P. Secchi's *Le Soleil* (1875), I find at p. 285, vol. i., in his special "Description du spectre solaire," the following very apposite remark touching the chief subject of this paper:—

"Certaines bandes qui, dans les instruments ordinaires, paraissent comme estompées, sont en realité composées d'un grand nombre de lignes parfaitement distinctes, comme on le voit avec un spectroscope ayant un grand pouvoir dispersif; mais quelques-unes d'entre elles sont réellement diffuses sur les bords, et il est impossible de les décomposer, quelle que soit la puissance de l'instrument que l'on emploie. Nous pouvons citer comme exemple les raies du groupe B."

Hence it would appear pretty certain, though I have not been able to find in the book any account of direct and particular attempts to resolve the lines of B, that what was accomplished last June in Lisbon, and is detailed in the present paper, is happily more than that laborious and brilliant spectroscopist, the regretted P. A. Secchi, S.J., had himself seen, or even expected would ever be seen "in the group B" by anyone else.

Collected Micrometer Measures, reduced to Spectrum Place by Wave-number in a British Inch, of the Great B Line and its Bands, founding on Angstrom's Normal Solar Spectrum.

Object observed.		Rudely estimated Intensity.	Obs. of June 15, 1878, $10^h\ 30^m$ a.m. Dispersion 39°.	Obs. of June 19, at $11^h\ 50^m$ a.m. Dispersion 50°.	Obs. of June 19, at $0^h\ 30^m$ p.m. Dispersion 50°.	Concluded Mean for every Line.	Single Lines and Centres of Double Lines.	Differences. Width of Doubles.	Dist. of sides.	Dist. of centres.
Previous stop line, place assumed from Angstrom		1·5	36,663	36,663	36,663	36,663	36,663			
A very faint line		0·1			(36,679)	(36,679)	(36,679)		28	31
PRELIMINARY BAND.										
First pair, Component	1	0·5	36,690	36,689	36,692	36,691	36,692	3		
	2	0·5	692	692	695	694			23	27
Second pair, Component	1	0·7	36,715	36,718	36,718	36,717	36,719	4		
	2	0·7	718	721	723	721			21	25
Third pair, Component	1	1·0	36,741	36,742	36,743	36,742	36.744	5		
	2	1·0	746	746	748	747			20	26
Fourth pair, Component	1	1·5	36,767	36,766	36,768	36,767	36,770	6		
	2	1·5	773	771	774	773			19	25
Fifth pair, Component	1	1·8	36.793	36,790	36,792	36,792	36,795	6		
	2	1·8	800	796	798	798			16	22

Object observed.		Rudely estimated Intensity.	Obs. of June 15, 1878, $10^h\ 30^m$ a.m. Dispersion 39°.	Obs. of June 19, at $11^h\ 50^m$ a.m. Dispersion 50°.	Obs. of June 19, at $0^h\ 30^m$ p.m. Dispersion 50°.	Concluded Mean for every Line.	Single Lines and Centres of Double Lines.	Differences. Width of Doubles.	Dist. of sides.	Dist. of centres.
Sixth pair, Component	1	2·0	36,817	36,812	36,814	36,814	36,817	7		
	2	2·0	826	818	819	821			14	21
Seventh pair, Component	1	2·5	36,840	36,833	36,834	36,835	36,838	6		
	2	2·5	848	839	839	841			14	20
Eighth pair, Component	1	2·5	36,860	36,854	36,853	36,855	36,858	5		
	2	2·5	867	858	858	860			14	18
Ninth pair, Component	1	2·0	36,879	36,874	36,874	36,874	36,876	5		
	2	2·0	884	878	878	879			12	16
Tenth pair, Component	1	1·5	36,897	36,890	36,889	36,891	36,892	3		
	2	1·5	900	893	892	894			13	15
Eleventh line, of Preliminary band, a Single one		1·0	36,912	36,904	36,906	36,907	36,907		(17)	(19)
ATTACHED BAND.										
First pair, Component	1	0·3	36,923	36,923	36,925	36,924	36,926	4		
	2	0·3	927	927	930	928			6	10

Second pair, Component	1	0·5	36,930	36,933	36,937	36,934	36,936	3		
	2	0·5	934	936	940	937			5	7
Third pair, Component	1	0·8	36,939	36,943	36,944	36,942	36,943	2		
	2	0·8	944	945	946	944			5	8?
Fourth pair?		1·0	36,949	36,950	36,949	36,949?	36,951?			
Fifth pair?		1·0	36,955	36,953	36,953	36,954			5?	5?
Sixth pair?		0·8		36,957	36,958	36,958	36,956?		4?	—
A strong single line		2·0	36,961	36,962	36,962	36,962	36,962		4?	
Another ditto		2·0	36,968	36,968	36,968	36,968	36,968		6	6
Another fainter		1·5	36,975	36,975	36,974	36,975	36,975		7	7
									(7)	(8)
B Line.										
First side of bundle		3·0	36,984	36,983	36,982	36,982	36,983		2	
Second ditto					984	984				
Pale space begins					36,984	36,984				7
Ditto ends					988	990				
Terminal line		2·0	36,994	36,990	36,988	36,990	36,990			

Some Remarks on the Total Solar Eclipse of July 29, 1878.

By Arthur Schuster, Ph.D., F.R.A.S.

I venture to lay before the Society a few results which I have obtained during the recent total solar eclipse in Colorado, and also some theoretical considerations, which I hope may help in the discussion of other observations.

I was stationed at West Los Animas, the capital of South Colorado. The telescope, with a 4½-inch objective, belonged to Colonel Campbell, of Blytheswood, and my best thanks are due to him for his generosity in placing the instrument at my disposal. The spectroscope had a single prism of dense white flint.

Several hours before the eclipse I covered my left eye, which I intended to use during the eclipse, with a piece of black velvet; all observations before totality were made with my right eye. The enormous extent to which the eye is rendered more sensitive by being kept in the dark is seldom realised. Half-an-hour before the eclipse I uncovered the eye for a few seconds. A sheet of white paper which to my right eye looked a dull white, appeared so dazzling to my left eye that I could not bear to look at it.

I watched the solar spectrum as the Moon gradually began to cover the solar disk, and I was greatly struck with the fact that the violet lines came out so very much more clearly than I ever remembered having seen them under the same circumstances. Although at the time I considered this an apparent effect due to the fact that the general illumination was diminishing and the eye becoming more sensitive, it was so striking that I continued to make notes on the subject until ten minutes before totality, when I could see beyond K. After the end of totality Prof. Eastman told me that he was struck by the great distinctness of the violet lines before totality, and Prof. Young mentions, in the account of his observations, that ten minutes before totality he could, with a fluorescent eye-piece, see dark lines quite to O, and rather better than before the eclipse began. I cannot now consider that this fact, which was so conspicuous as to have struck three independent observers not looking out for it, was simply due to an effect of contrast. In my own instrument, for instance, the general illumination had little to do with the visibility of any lines. It is the intensity of the rays in the blue which weaken the sensitiveness of the eye for the violet, and the intensity of these rays did not decrease as the eclipse proceeded.

I believe I can offer an explanation of the phenomenon. It is well known that under different atmospheric conditions, which even apparently may be alike in every other respect, the

blue end of the solar spectrum is sometimes very vivid, sometimes not visible; and it is easy to imagine that the cooling effect of the eclipse should produce the change from one of these atmospheric conditions to the other. We know, for instance, that aqueous vapour absorbs the violet rays; on the other hand water is, after quartz, the most transparent substance for the ultraviolet. If we assume that the cooling which takes place during the eclipse condenses part of the aqueous vapour, it would follow as a natural consequence that the violet rays should come out more distinctly.

Ten minutes before totality I began to watch the eclipse, in order to see whether the corona was going to be visible before totality. I looked through one tube of an ordinary opera glass; but totality was close at hand before the corona was visible. A chronometer was standing close by me, and I began to count seconds from the time I saw the corona up to the time the last ray of the sun disappeared. I counted six seconds. I then went to my spectroscope, which previously had been pointed to the violet end. My friend, Mr. Haskins, Fellow of St. John's College, Cambridge, was at the finder, and we had previously agreed that unless he saw a large prominence he should point the telescope to the brightest part of the corona. He pointed it to the corona, and I was struck by the intensity of the continuous spectrum. I could see into the violet as far as wave-length 4070, which is further into the violet than the hydrogen line *h*. Widening or narrowing the slit seemed to have no appreciable effect on the limit of the spectrum. I then asked Mr. Haskins to point the telescope to a point further removed from the Moon, and he accordingly pointed it to a part which was three-tenths of the lunar diameter away. I could see no change in the intensity of the spectrum. I next moved the telescope of the spectroscope into the green, and was at first sight startled by not seeing the green line. Looking again at the place, I thought I could discover two faint lines,* but before I could register their position the bright chromospheric lines appeared, and remained for several seconds after the Sun had reappeared.

I saw no dark lines crossing the continuous spectrum. That these dark lines existed I have no doubt, from the observations of Profs. Barker and Morton, who observed in Dr. Henry Draper's party. Yet others beside myself have not seen the dark lines, and I consider this strong evidence that only part, and perhaps only a small part, of the continuous spectrum is due to reflected sunlight.

The polariscope is likely to give us information as to the proportion of scattered light in the corona. I have calculated the amount of polarization due to the scattering of a particle illuminated by a spherical surface. The whole light scattered from such a particle can be divided into two parts. One part

* Prof. Eastman tells me that he suspected a green line more refracted than 1474 K.

is equal to that which would be scattered by the particle if a source of light shining with an intensity

$$\pi S r^2 \cos\omega$$

were placed at the centre of the sphere; the other part is equal to that which would be sent out by the particle itself, if it was luminous and shining with an intensity

$$\frac{2\pi}{3} AS (2 - 3\cos\omega + \cos^2\omega).$$

In these expressions S is the intensity of the light sent out normally by the unit surface of the sphere; ω is the angle subtended at the particle by a line drawn to the centre of the sphere and a tangent to the sphere; A is the proportion of the light scattered by a particle in any direction if the incident light is polarized in a plane containing the incident and scattered ray; r is the radius of the luminous sphere. If we decompose the scattered light into two components, one polarized in a plane passing through the Sun's centre, the other at right angles to it, the proportion of the second component to the first will be

$$1 - 3\sin^2\phi \frac{\cos\omega + \cos^2\omega}{4 + \cos\omega + \cos^2\omega}.$$

In this expression ϕ is the angle subtended at the particle by the Sun's centre and the scattered ray.

It appears from these expressions that close to the surface of the Sun, where ω is a right angle, the light scattered from a particle is entirely unpolarized; that as the particle is removed from the Sun, the polarization in any direction increases, until finally, when the particle is at an infinite distance, ω vanishes and the polarization is complete in a direction normal to the incident ray. The polarization therefore ought to increase as we go away from the Sun. I have only taken a single particle into account. As the line of vision directed to the edge of the Sun will pass through particles which are away from the Sun, the light even in this direction will be polarized; but in any case the polarization ought to increase as we go away from the Sun.

These theoretical considerations teach us the amount of polarization in light scattered from a certain fixed number of particles placed at different distances from the Sun. If we could combine with this an accurate measurement of the percentage o' polarized light actually sent out by the corona, we should b able to determine the relative number of scattering particles a different distances, and also the proportion of scattered light t the light due to the incandescence of the particles and oth causes, such as ordinary reflection. That we should in this v gain most important information will be obvious to everybo'

As a matter of observation the amount of polarization f first to increase with the distance from the Sun, re maximum, and then to decrease rapidly. The maxim polarization was first observed by Mr. Prazmowski durir

eclipse of July 1860. It was confirmed by Janssen in 1871; and during the same eclipse Mr. Winter took two measurements, one close to the Sun and one a few minutes away from the Sun. The polarization at the latter place was half as much again as close to the limb of the Sun. During the recent eclipse Prof. Arthur Wright took a series of very careful measurements, but only began a few minutes away from the Sun. He observed a rapid decrease as the distance increased. The reason why the polarization close to the Sun is smaller than at a distance of a few minutes is obvious from our theoretical discussion. The fact that a maximum is reached after which the polarization rapidly decreases admits of only one explanation: that the particles begin to be too coarse to polarize the light in the act of scattering.

The exact determination of the point of maximum polarization must in future form one of the most important parts of eclipse observation. A variation of this distance during different eclipses, which will probably be observed, will lead to important conclusions.

There is one more point to which I wish to draw the attention of the Society. It is well known that during the eclipses of the last few years the Sun's corona was found to be approximately symmetrical round an axis which has been designated sometimes as the axis of the Sun, sometimes as the axis of the ecliptic. The two are inclined at an angle which, as seen from the Earth, varies between over 7° 15′ and nothing. If the corona is of cosmic origin, there is no reason why the corona should be drawn out exactly in the ecliptic, though there may be reason that it should be drawn out approximately in the ecliptic. On the other hand, if the corona is a solar atmosphere, the symmetry should be round the axis of the Sun. It would be a matter of interest to mark on drawings and photographs of the corona not only the Sun's equator, but also the ecliptic. The inclination of these two lines during the eclipse of 1871 was more than 7°. A cursory examination of Colonel Tennant's photographs has led me to think that during that eclipse the corona was symmetrical neither exactly round the solar axis nor round the axis of the ecliptic, but nearer the former than the latter. The point which I wish to bring forward, however, is not this symmetry, but a variation from symmetry which is nearly always observed. The corona has generally been found to be drawn out more in one direction than in another diametrically opposed to it, and the remarkable fact is that the eclipses of 1874 and 1875, which happened at an interval of very nearly a year, so that the Sun and Earth were nearly in the same relative position, resembled each other not only in general features, but also in the fact that the corona was developed more towards the north than it was towards the south. That this fact has some meaning I have no doubt, but what this meaning is can only be made out by a careful examination of the outlines of the corona as seen from different relative positions of Sun and Earth.

The Total Eclipse of the Sun, July 29, 1878.

By F. C. Penrose, Esq.

In company with three members of this Society and some others, I embarked on board one of the steamers of the White Star Line (the Germanic) and afterwards proceeded, with the larger portion of the party, to Denver, in Colorado, for the purpose of observing this eclipse. I took up a position on the outskirts of Denver, in N. latitude 39° 46′ 29″ and W. longitude 105° 1′ 43″, as ascertained by triangulation from a standard point in Denver, the altitude above the sea level being about 5,500 feet.

The threatening weather of the eight days previous to the eclipse had pointed out the propriety of the observing parties being separated, and this we had done to some extent. Mr. Ranyard was with Professor Young about 5 miles distant and Mr. Lodor and his party were at an intermediate point in Denver itself. I was assisted by Mr. Baldwin, a young gentleman of Denver who had been introduced to me through Professor Young. I used a $2\frac{1}{4}$-inch achromatic by Troughton & Simms, with power 30 and field of view 74′.

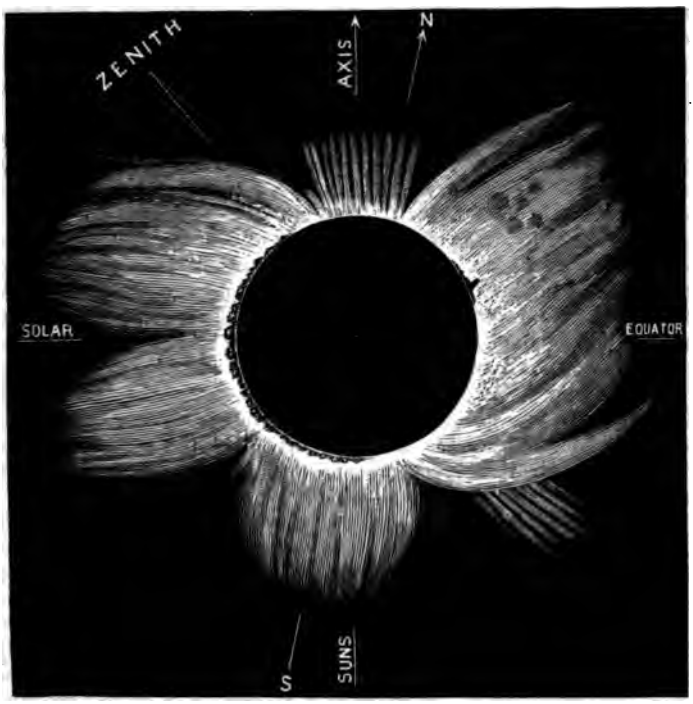
My principal object was to draw the corona, but I also endeavoured, so far as it did not interfere with my main purpose, to note the time of the four principal phases. In this I partly succeeded; but, owing to the hurry which resulted from having to rearrange some defences against the wind, which was blowing rather fresh, I did not get a good observation of first contact. The wind fell as the eclipse advanced, and nothing could be more favourable than the atmospheric conditions. My observation of second contact was better, but I consider it uncertain to about two seconds. As for the two last, I have no reason for supposing them to be more than a second in error.

	Local M.T. h	m	s
First contact	2	19	29·4
Second contact	3	28	51·5
Third contact	3	31	35·6
Fourth contact	4	34	49·6

As totality approached I was much struck with the shortness and apparently equal width and blunted ends of the diminishing remnant of the photosphere. I saw no sign of Baily's beads, and the white light was extinguished at once, like a gas lamp turned off suddenly. I withdrew at once the grey screen I had been using and saw the rosy tints of the chromosphere and immediately afterwards the silvery corona.

My companion called the time during the first minute, during which I passed the scale which I had in the eye-piece completely round the Moon, and ascertained that I could trace the extent of the corona for 28 minutes of arc in the direction of the

eastwards, and nearly as far, but not quite, in the opposite direction, but nowhere else so far. I then made some pencil records of the streamers of the corona and occupied myself during the short remainder of the time in studying its (true) northern half, and in the drawing whatever is shown of this half



should have more weight attached to it than to the other. I took but little notice of the prominences, but could not help observing a bright hooked one which appeared to me to shoot out towards the east not long before totality ended. I believe some other observers noticed two hooked prominences in the same neighbourhood.

Almost directly after totality had ceased I left the telescope to the care of my companion and went aside and made a coloured drawing of what I had just witnessed, and it is from this rough sketch and the lines drawn during totality that the drawing has been composed. I have, however, added to it, in a paler tone of colour, some features which have been supplied to me by Professor Cleveland Abbé and which has been confirmed by other observers, namely Mr. Lockyer, who observed

during part of the time, and Dr. Edmunds, of Denver, who observed throughout with the naked eye and saw streamers at a much greater distance than could be seen in the telescope, of the similitude of a wind vane. I looked up for about a second without the telescope and saw nothing but the intensely black Moon surrounded, or nearly so, with a rosy garland apparently of much greater width than the sierra had appeared in the telescope, but I did not look long enough to get my eye into focus. Professor Abbé has described these streamers as having, in his opinion, a meteoric origin, and I have made a diagram which shows that none of the lines which either these observers or I have recorded is inconsistent with this view.

The pointed ends of the "wind vane," of which I have given the observed lines in red, seem to favour the explanation of an elliptic orbit of considerable major axis and great excentricity, such as would fall in with the blue lines. The wedge-like point proceeding from the north pole of the Sun would agree with a similar figure, whilst some of the others can be explained by orbits of meteors of less extent. It is obviously not requisite that the Sun's centre should be the focus of the apparent orbit, as it would be modified from the real figure by perspective. The red lines on the diagram, with the exception of those belonging to the "wind vane," are all of them enlargements of the lines which I mapped down during totality, without having any idea or theory of the possible meteoric origin of the corona; which, however, both the spectroscopic and eye observations seem to combine in rendering probable.*

I am far from arguing that this theory answers for the whole of the corona, and I much doubt whether it will explain the almost equal and radial lines which proceeded from the neighbourhood of the Sun's north pole, and which appeared to me the most beautiful part of the whole. There was also something analogous near the Sun's south pole, but not so clearly radial. I did not, however, examine this part so closely. The rays proceeding from the north pole seemed of a rather warmer colour than the rest of the corona, and I thought, but am not

* For want of space the woodcut does not give the more distant streamers &c. referred to in the text as seen by the naked eye, but is confined to my own observations: neither does it attempt to represent the blackness of the Moon. In the drawing I found it necessary to embody the particulars referred to for the purpose of giving a truer rendering of the background upon which I saw the corona projected. I had myself noticed and recorded during totality that it seemed to shade off imperceptibly in the direction of the solar equator, both east and west, whilst its termination was clearly defined in other directions: a uniform ground therefore would not have been correct.—F. C. P.

The diagram referred to in the text, as well as the drawing showing additional streamers observed by Prof. Cleveland Abbé, Mr. Lockyer, Dr. Edmunds, can be referred to at the Society's apartments.—Ed.

sure, that there was some slight movement or palpitation at their extremities.

In the eastern part of the corona there seemed to be, but only faintly, some signs of dapplings of a darker grey than the rest. Were these perhaps meteor streams seen from the Earth in section and so rather intercepting the light of the more luminous parts? It will be remembered that, judging from the analogy of the November meteors, these bodies may not be uniformly scattered in their orbits, and it may easily happen that the part where the meteoric bodies are thickest may be too far from the Sun to receive much illumination. Just after the reappearance of the Sun several serpentine fringes were seen moving southwards along the ground, at no great distance apart and at an estimated pace of about 5 miles an hour, and about 8 inches broad. They were brown themselves, but the light between them was of a golden hue.

I must not conclude without a word of recognition of the kindness we received from the American astronomers, of the liberality of the railroad authorities of the United States, and the co-operation of the company and officers of the White Star Line of steamers.

November 1878.

On the progress of the Reductions connected with the Ascension Expedition. By David Gill, Esq.

I beg to submit to the Society the following report on the observations of *Mars* made at Ascension.

1. The observations for time, made with the 30-inch transit instrument by Cooke, belonging to the Society, have been reduced. Time was determined, as a rule, each second or third day, and by comparisons at the time the error of each of the five chronometers was ascertained.

The error of the chronometer used when observing *Mars* was then deduced for intermediate intervals from its comparison with the stationary chronometers, and thus four independent determinations of its error before and after each series of observations were obtained. On no single occasion, however, do the results so obtained differ half a second from the interpolated rate of the observing chronometer.

2. The observations of the Sun, made at St. Helena and Ascension with the reflecting circle, to determine local time, are also reduced; the following are the results for difference of longitude:—

Ascension west of St. Helena.

		Without Temperature Corrections.			With Temperature Corrections.		
		h	m	s	h	m	s
By Chronometer	B	+0	34	46·61	+0	34	46·19
	C			48·04			47·89
	E			41·94			43·46
	F			46·05			45·91
Mean		0	34	45·66 ± 1·02	0	34	45·86 ± 0·61

The results in the left hand column were obtained in the ordinary way by adopting for the rate at sea the mean of the rates determined before and after the voyage, at St. Helena and Ascension respectively.

The results in the right hand column were obtained by the application of corrections for temperature, the coefficients for each chronometer having been determined from trials made by Mr. Hartnup at Liverpool. The temperature was determined by chronometer D, an uncompensated chronometer, acting as a chronometric thermometer. The introduction of the temperature corrections diminishes the probable error of the result by nearly one-half. The observations at St. Helena were made on the steps of the principal entrance of Johnson's Observatory; the observations at Ascension at a small pillar in Garrison, built for the convenience of navigating officers and their observations for time.

The original site of the Transit Hut in Garrison was 16 feet to the east and 160 feet to the south of this pillar. But all the observations of *Mars*, excepting those of July 31, were made not in Garrison, but at Mars Bay. Accordingly, after the observations at Mars Bay were finished, the difference of longitude between Mars Bay and Garrison was determined by chronometers, as follows:—

	h	m	s	s
Mars Bay W. of old Magnetic Observatory in Garrison	−0	0	3·29	± 0·23
Old Magnetic Observatory W. of observing pillar 502 ft.	−0	0	0·37	
Observing pillar W. of Johnson's Observatory, St. Helena	+0	34	45·86	± 0·61
Mars Bay (Transit Hut) W. of Johnson's Observatory	+0	34	42·20	± 0·66
Johnson gave for longitude of his Observatory	+0	22	54·60	
Hence, according to Johnson, Mars Bay W. of Greenwich	0	57	36·80	

Only 3 occultations were observed at the dark limb of the Moon at Mars Bay. These were reduced, employing Newcomb's corrections to Hansen's Tables of the Moon, and recent Greenwich observations of the occulted stars, kindly communicated by the Astronomer Royal. The results for longitude are

		h	m	s
Sept. 14	By disappearance of B.A.C. 6063	0	57	44·80
Sept. 18	„ disappearance of 31 *Capricorni*	0	57	40·08
Oct. 3	„ reappearance of ρ *Leonis*	0	57	39·87

I have adopted provisionally

	h	m	s
Mars Bay (Transit Hut) W. of Greenwich	+0	57	39
Garrison „ „	+	57	42

As a rigid determination of the tabular errors of *Mars* was one object I had in view, further means were taken to secure a satisfactory longitude. A number of Moon culminations were observed with the transit instrument, and a number of distances of the Moon from stars were measured by means of the heliometer.* The latter, I believe, will give results of great accuracy if I can succeed in satisfactorily determining the errors of the Lunar Tables. I have received the Greenwich and Strasburg observations, but wait those of Washington and Paris. The lunar distances measured by the heliometer are also available for testing how far it will be possible to apply the diurnal displacement to the determination of the lunar parallax. I believe it will be found to be the best of all methods for determining this important constant.

Since a small error in the adopted longitude does not in any way affect the resulting solar parallax, and since the correction for an error in longitude can be applied at the end to the resulting tabular error, I intend to postpone the further discussion of the longitude till the other more important results are completed.

3. The latitude was determined in the first place by Talcott's method. The micrometer of the transit instrument was turned round 90°; and so, by its means, the difference of zenith distance of two stars, culminating on opposite sides of the zenith, was observed. The level of the setting circle, however, was far from sensitive, and I could not succeed in substituting for it a more sensitive bubble. I tried to attach the bubble of the cross level to the setting circle, but could not succeed, with the appliances at my disposal, in making the attachment rigid enough to bear reversal and re-reversal with consistent results.

* I must here express my obligations to our Fellow, Mr. Penrose, for the admirable charts he constructed for me, by which I was able to make the observations referred to. By methods he has already explained to the Society, he laid down graphically the apparent path of the Moon at Ascension, and the apparent places of the stars within reach of measurement. From these charts the distance and position angle of the Moon from neighbouring stars could be read off with all the accuracy required for setting. By similar methods he predicted the occultations of all stars of the *Nautical Almanac* list which would be visible at Ascension on the nights I was at liberty to observe them.

By taking great pains to bring up the bubble to the same point, in the same way opposite sides of the zenith, I made the best observations I could. On the last night at Mars Bay I removed the roof of the Transit hut, and observed stars in the prime vertical. The results, from both methods, proved on reduction to be much more accurate than I expected, and both gave for the geographical latitude

°	′	″
−7	59	15·5.

4. The tabular quantities have been computed as follows:—

(1) The geocentric apparent places of *Mars* for each day at Greenwich mean noon were computed with all the accuracy Leverrier's Tables will give, and then, by changing one or two hundredths of a second of arc here and there, the second differences were found to run smoothly. For each period of observation the places were then computed for intervals sufficiently short to require interpolation with first differences only.

(2) From the meridian observations at Greenwich (communicated by the Astronomer Royal), the tabular heliocentric longitude of *Mars* was found to require a correction of $-2''{\cdot}45$. The equivalents of this correction in geocentric right ascension and declination were computed and tabulated for each day.

(3) Tables were constructed giving at sight for any hour angle, and for any declination (within the limits of $-9°$ and $-13°$ Decl.), the parallax in right ascension and declination of a celestial object whose distance is *unity*, observed at Ascension—on an assumed value of the mean solar horizontal parallax. A table also was constructed giving the value of $\log \frac{1}{\Delta}$ for *Mars*, so that the computation of the tabular parallax in R.A. and Decl. was reduced to the addition of two logarithms.

(4) The corrections of the stars of comparison, from mean to apparent place, were computed for each fifth day during the period of observation, and rigidly interpolated for every day at Greenwich midnight. The corrections depending on the longitude of the Sun and Moon's perigee, which are omitted in the *Nautical Almanac* day numbers, were not taken into account, as they were also omitted in computing the apparent place of the planet.

From the tables so formed the correction to apparent place was easily taken out at sight for the instant of observation; and this was applied to the mean place of the

star derived from the meridian observations, as given in the preceding paper.*

(5) With the apparent place of the star so found, and with the place of the planet found as in § (1), corrected for tabular error and parallax, §§ (2) and (3), the tabular distance of centres of the star and planet were computed by the formulæ

$$\sin \frac{1}{2} s \sin p_o = \cos \frac{1}{2} (\delta' + \delta) \sin \frac{1}{2} (\alpha' - \alpha),$$

$$\sin \frac{1}{2} s \cos p_o = \sin \frac{1}{2} (\delta' - \delta) \cos \frac{1}{2} (\alpha' - \alpha),$$

where α and δ denote the R.A. and Decl. of the star, α' and δ' the R.A. and Decl. of the planet, s the angular distance of centres, and p_o the mean position angle of the great circle joining star and planet.

(6) The factors in R.A. and Decl., or the effect on the distance of increasing the R.A. and Decl. of the planet by $+1''$, were computed by the formula

$$\text{Factor in R.A.} = f' = \sin p_o \cos \delta,$$

$$\text{Decl.} = f'' = \cos p_o.$$

The parallax factor, or the effect on the distance of increasing the assumed parallax $\frac{1}{100}$ part, was

$$f''' = \frac{f' \times \text{Parallax in R.A.} + f'' \times \text{Parallax in Decl.}}{100}.$$

In this way all the tabular quantities were carefully computed, and in a manner which left hardly any possibility of error.

Take for example :—

* The paper referred to will be printed in the next number of the *Monthly Notices*.

Obs. cccxvii. Sept. 9. Morning. *Mars* and *g*. $\log \frac{i}{\Delta}$ 0·41954.

Rotation No.	Time by Chronometer.	Greenwich Mean Time.	Uncorrected Tabular R.A. of Planet.	Uncorrected Tabular Decl. of Planet.	Star's apparent R.A.	Star's apparent Decl.	Corrections of Tabular Place of the Planet. R.A.	Corrections of Tabular Place of the Planet. Decl.
		d	° ′ ″	° ′ ″		° ′ ″	″	″
1331	3 15 24	9·70624	346 2 6·79	−12 27 49·18	347 14 59·93	−12 13 41·68	−8·46	−3·43
1332	18 57	·70869	4·43	49·68				
1333	20 59	·71010	3·07	49·96				
1334	24 0	·71220	1·05	50·38				

Rotation No.	Parallax in R.A.	Parallax in Decl.	Distance.	p_0		f''	f'''
			″	° ′			
1331	−20·92	+0·90	4383·89	258 49·2	−0·981	−0·194	+0·204
1332	−21·09	+0·97	86·41	49·3	− ·981	·194	·205
1333	−21·18	+1·01	87·84	49·3	− ·981	·194	·206
1334	−21·31	+1·07	89·98	49·3	− ·981	·194	·207

The independent computation of each tabular quantity enables each bisection to be compared with the tabular result, and any accidental errors to be examined. The factors also enable the individual computations to be used to check each other.

In this way the tabular quantities for 104 observations made between September 4 and September 11 have been computed with great care, and thoroughly checked. The same work is far advanced for the whole of the observations.

5. In computing the instrumental distances—

The results of the division error investigations, made in connection with the *Juno* observations, have been adopted.

The errors of the screw were reinvestigated at Ascension by observations made on 28 days, by a process similar to that employed in connection with the *Juno* observations. In the present case, however, the results rest on a much more perfect series of measures, for spaces equal to $0^{r}\cdot4$, $0^{r}\cdot8$, $1^{r}\cdot2$, and $2^{r}\cdot0$ were measured by all different parts of the screw. The following expressions were found to represent all the series satisfactorily.

For readings on Scale A:

$$0\cdot1518\cos u - 0\cdot0586\sin u - 0\cdot0112\cos 2u + 0\cdot0192\sin 2u - \cdot0120\,n + \cdot0667\,n^2 + \cdot0045\,n^3 - \cdot0050\,n^4;$$

For readings on Scale B:

$$0\cdot2075\cos u - 0\cdot0906\sin u + 0\cdot0053\cos 2u + 0\cdot0269\sin 2u - \cdot0238\,n - \cdot0071\,n^2 + \cdot0075\,n^3 + \cdot0106\,n^4;$$

where the unit is $\frac{1}{100}$ of a screw revolution, and where n is the number of revolutions reckoned from $2^{r}\cdot0$.

The curves which represent these expressions will be found exactly similar, except that the periodic error and the error depending on the number of revolutions are slightly greater when the reading is made on Scale B than when it is made on Scale A. This error is due to the form of the Repsold micrometer, and the probability of its existence had already been anticipated (see *Dun Echt Observatory Publications*, vol. ii., p. 53); the screw errors were purposely determined independently for each scale, in order to find out if a difference of errors would really be found to exist. The greatest divergence of the two curves from mean, however, does not amount to $\frac{1}{50}$ of a second of arc, so that in practice the mean of the two curves has been employed. The run of the screw was found, from a great number of determinations, to be practically constant, and a correction for this was included in the Table of Screw Errors.

The correction for index error was also nearly constant, so that $+1^{r}\cdot15$ added to the readings of Scale B made the arithmetical difference of the scale readings very nearly the true

distance, at least with abundant accuracy for computing the refraction.

The correction to be applied to the measured distance for the effects of refraction was computed by the very accurate formula of Hansen, and the accompanying tables, given by Dr. Seeliger, in his *Theorie des Heliometers*, pp. 96–99:

$$\Delta s = as\,[1 + \tan^2 z_o \cos^2 (p_o - q_o)] + a's \sin^2 (p_o^\circ - q_o),$$

where

s is the apparent distance,

q_o the parallactic angle of the middle point between the star and planet,

z_o the true zenith distance of the middle point between the star and planet.

For a and a' the logs are given by Dr. Seeliger's tables.

The correction of the mean refraction for the readings of the meteorological instruments was computed as follows:—

For each set of readings of the barometer and thermometer the logarithm of the meteorological factor, according to Bessel, was rigidly computed, and from the figures so obtained a curve was constructed giving the log. factors for each instant of observation.

The true correction for refraction was thus obtained in terms of revolutions of the micrometer screw; and this correction, applied to the instrumental readings, gave the true distance measured in terms of the micrometer screw. These readings were then converted into arc by employing a very approximate value of the screw, deduced from observations of the mutual distances of the comparison stars, whose places were determined by numerous meridian observations. (1 rev. = 25″·7270.)

Finally, a correction for defective illumination was applied equal to + or − half the defect of illumination along that diameter of the planet whose position angle is the same as the position angle of the planet referred to the star of comparison.

This correction was computed as follows:—

If Q = the position angle of greatest defect of illumination,

M = areocentric angle between the Earth and Sun,

p° = the position angle of the planet relative to the star of comparison,

ρ = planet's true radius, and

$\tan m = \tan \mathrm{M} \cos (p_o - \mathrm{Q})$,

then

$$\left.\begin{array}{l}\text{Correction for distance of centres of star and planet,}\\ \text{when both limbs have been observed}\end{array}\right\} = \rho \sin^2 \frac{1}{2} m.$$

The values of Q and M were taken from Mr. Marth's Ephemeris (*Monthly Notices* for April 1877). In the observations in question this correction is nearly insensible.

6. And now for the all-important question as to how the observations were made, and what precautions taken to eliminate systematic error.

The axis of the heliometer tube having been directed to the middle point between the star and the planet, the position circle set to the computed position angle, and the segments separated to the computed distance, the planet and star appear together in the field of view. Unless the star is very bright, it is found that whenever the observer attempts to place it in the centre of the planet or on the limb of the planet, the star disappears. I had therefore provided myself with three screens, made by Mr. Browning, consisting of one, two, and three folds of wire gauze respectively, any one of which could at pleasure be attached to the head of the instrument. By a small handle at the eye end the screen can be laid over either segment of the object-glass at pleasure; and, in practice, I found the three-fold screen the best for use with *Mars*. With this screen, when the definition was steady, the planet appeared as a clear, sharply defined disk of a dull copper colour, the markings being just visible. It was now easy enough to see the comparison star, when brighter than 8th magnitude, either in the centre of the disk or on the limb of the planet.

An important addition to the heliometer was the small reversing prism, which I exhibited at the meeting of the Society in June 1877.

This prism, attached to a revolving plate on the eye-piece, enabled me not only to measure in all position angles as if the line joining the star and planet was always horizontal, but also to eliminate any tendency I might have to place the star always too much to the right or too much to the left of the planet, by simply reversing the prism 180° between each pair of bisections.

Thus the observations E. and W. of the meridian were made under precisely similar conditions, and were, so far as I can see, entirely free from all systematic error of bisection.

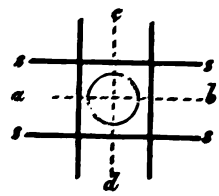
Two methods of observation were followed, which I shall call A and B.

In method A, the star is placed on the estimated centre of the planet, and the scales are read off; then the segments are reversed, the star again is placed in the estimated centre of the planet, and again the scales are read off. Now the small reversing prism is rotated 180°, and the star is placed again in the centre of the planet, and the scales are read off; and finally the segments are reversed to the original position, the star placed in the centre of the planet, and the scales read off. This constitutes one complete observation.

Of course the instant that the star has been placed in the estimated centre is noted by the chronometer, and written down before the scales are read.

When there is considerable phase some care is required in estimating the centre of the disk. The method I adopted was as follows:—

In the field of the eye-piece was a square formed by four flat gold wires; the centre of this square was approximately the true axis of the instrument. The lines *ss*, *ss* marked the direction of separation of the segments. Hence, having placed the planet in the centre of this square, the eye could estimate with great accuracy the imaginary lines *ab* and *cd* respectively parallel and at right angles to *ss*, *ss*, and such that at intersection the portion of each line illuminated by the planet is bisected. The observation may appear complicated in description, but it is easy enough in practice, and the eye appears to be very sensitive in estimating the symmetrical position of the star.



In method B the star is first placed in the centre of the planet, as in method A, and then immediately moved till its disk bisects limb I, time is noted, and the scale read off; the star is again placed in the centre of the planet, and immediately after limb II is bisected, time noted, and the scale read off; then the segments are reversed, and the same operation, in reverse order, is repeated. Thus if $\Delta\theta$ is the error of the assumed index correction, $\Delta\rho$ the error of the assumed radius of the planet, the four readings which make up a complete observation will be

$$\left.\begin{aligned} &s+\Delta\theta-\Delta\rho\\ &s+\Delta\theta+\Delta\rho\\ &s-\Delta\theta+\Delta\rho\\ &s-\Delta\theta-\Delta\rho \end{aligned}\right\} \text{ or } \left\{\begin{aligned} &s-\Delta\theta+\Delta\rho\\ &s-\Delta\theta-\Delta\rho\\ &s+\Delta\theta-\Delta\rho\\ &s+\Delta\theta+\Delta\rho \end{aligned}\right.$$

And this order was always observed.

During the week September (4–11), the observations of which are discussed in the present paper, method B was chiefly employed, in deference to the opinion of the Astronomer Royal; but there are many observations made by method A, and many by method B, not yet reduced.

As an example of the reduction of an observation, I shall take the same case that I have used to illustrate the tabular quantities. (*See* next page.)

I believe the following are the only systematic errors which observations made in the manner I have described can be imagined to be subject to:—

1. Errors of the scale and screw.
2. Errors of the assumed scale or screw value (possibly of a temporary character).
3. Errors of the refraction correction.

Obs. cccxvii. *Mars* and *g*. Sept. 9. Morning.

Rotation No.	Difference of Scale Readings Corrected for Approx. Index Error.	Refraction.	True Instrumental Distance.	In Arc.	Obs. Corrected for $\rho \pm 12''.27$.	Tabular Distance.	O−C.
	r			"	'	"	"
1331	$169{\cdot}713 - \Delta\theta$	·1915	169·9045	4371·13	4383·40	4383·89	$-0{\cdot}49 + \Delta\theta + \Delta\rho$
1332	$170{\cdot}723 - \Delta\theta$	·2034	170·9264	97·42	85·15	86·41	$-1{\cdot}26 + \Delta\theta - \Delta\rho$
1333	$170{\cdot}762 + \Delta\theta$	·2100	170·9720	98·60	86·33	87·84	$-1{\cdot}51 - \Delta\theta - \Delta\rho$
1334	$169{\cdot}932 + \Delta\theta$	·2192	170·1512	77·49	89·76	89·98	$-0{\cdot}22 - \Delta\theta + \Delta\rho$
						Mean	−0·87

Of these sources of error I think I have already sufficiently discussed the first. The errors have been made the object of accurate study* and rigid correction; and even if the errors were much greater than they can possibly be imagined in the instrument in question, their effect on the result must entirely disappear when many different distances, some increasing, some diminishing, are measured.

The second source of error is best disposed of by considering the scale value unknown, and by so selecting the stars of comparison that it may be determined from the observations themselves. This of course implies that the star places are accurately known; but, for reasons which I shall afterwards explain more at length, I have considered this an essential condition in the problem from the beginning, and have provided for it accordingly.

As to the refraction, its effect is simply to diminish the apparent distance between the comparison stars on opposite sides of the planet; therefore, if a term is introduced proportional to the distance, the error of refraction will be almost entirely eliminated. If it is desired to ascertain, for example, how much an error of 1 per cent. in the assumed constant of refraction E. or W. of the meridian would affect the final result, it is easy enough to introduce such terms in the equations, and I propose to do so in the final discussion, though one can see beforehand that the effect must be almost entirely insensible.

The true distance is	$= O + \frac{O}{10{,}000} z + \epsilon$	Where O is the observed distance converted into arc 1 rev. = 25″·727, z the correction of this value in 10,000″, and ϵ the error of observation.
The true distance is also	$= C + \Delta C$	Where C is the computed tabular distance and ΔC the correction of the tabular distance to actual distance.

Also if

The true R.A.	$= \alpha + \Delta\alpha$	Where α is the tabular R.A.,
The true Decl.	$= \delta + \Delta\delta$	Where δ is the tabular Decl.,
And the true parallax	$= \pi + n \frac{\pi}{100}$,	

we shall then have

$$\Delta C = f'\Delta\alpha + f''\Delta\delta + f'''n. \qquad (1)$$

Hence

$$O + \frac{O}{10{,}000} z + \epsilon = C + f'\Delta\alpha + f''\Delta\delta + f'''n,$$

* See *Dun Echt Observatory Publications*, vol. ii. pp. 11–62.

or each observation will give an equation of the type

$$f'\Delta\alpha + f''\Delta\delta + f'''n - \frac{O}{10{,}000}\,\varepsilon - \epsilon = O - C. \qquad (2)$$

In the case I selected before we should have for example

$$-\cdot981\ \Delta\alpha - \cdot194\ \Delta\delta + 0\cdot206\ n - \cdot439\ \varepsilon - \epsilon = -0\cdot87.$$

Similarly each observation yields an equation of this form, in which ε must be considered different in each set of observations. That is to say, during an hour or two we may consider the scale value constant, or at least changing slowly, the effect of such change being eliminated by the order of arrangement of the observations; but we must not consider it uniform at all times. $\Delta\alpha$ and $\Delta\delta$ can, of course, only be considered uniform so long as we can suppose the tabular errors constant.

A preliminary solution showed that the tabular errors might be fairly represented by expanding them in terms of the time and distance, that is

$$\text{by substituting } \Delta\alpha + \frac{at}{\Delta} \text{ for } \Delta\alpha,$$

$$\text{and by substituting } \Delta\delta + \frac{bt}{\Delta} \text{ for } \Delta\delta,$$

where

t is the time reckoned from Sept. $8^d\cdot0$;

Δ the distance of the planet from the Earth, the Sun's mean distance being 1;

a and b the daily change of the tabular error in R.A. and Decl. respectively.

Neglecting the term ϵ, which is of course peculiar to each equation, and whose mean value we only desire to find, and making the above-mentioned substitution for $\Delta\alpha$ and $\Delta\delta$, the equations which result from the observations September 4 to 11 are as follows:—

Evening Observations, Sept. 4.

Star of Comp.	Rotation Number.								
									$''$
f	ccxxix	·467	$\Delta\alpha$ −·884	$\Delta\delta$ −4·52	a +8·55	b +·092	n −·309	ε =	1·38
k	ccxxx	−·678	+·735	+6·54	−7·09	−·137	−·355	=	−0·92
g	ccxxxi	·893	+·450	−8·58	−4·32	+·191	−·092	=	0·73
g	ccxxxii	·892	+·452	−8·55	−4·33	+·183	−·091	=	1·93
g	ccxxxiii	·891	+·454	−8·53	−4·34	+·177	−·091	=	1·70
g	ccxxxiv	·891	+·455	−8·51	−4·35	+·170	−·090	=	0·60
k	ccxxxv	−·687	+·727	+6·54	−6·92	−·123	−·357	=	−1·28
f	ccxxxvi	·447	−·895	−4·25	+8·50	+·079	−·308	=	1·06

Evening Observations, Sept. 5.

| Star of Comp. | Rotation Number. | | |

Star of Comp.	Rotation Number.							
								"
e	cclxxii	·993	+·120	−3·55	−0·43	−·146	−·566	= 1·50
h	cclxxiii	−·994	+·105	+3·50	−0·37	+·169	−·345	= −1·29
g	cclxxiv	−·992	−·124	+3·43	+0·43	+·190	−·144	= −1·69

Evening Observations, Sept. 7.

h	cclxxvi	−·999	Δ*a* +·050	Δδ +1·72	*a* −0·09	*b* −·219	*n* −·406	*z* = −0·46
e	cclxxvii	·995	+·103	−1·67	−0·17	+·209	−·499	= 0·64
e	cclxxviii	·995	+·101	−1·55	−0·16	+·171	−·495	= 0·93
g	cclxxix	−·986	−·166	+1·52	+0·26	−·162	−·212	= −1·31
g	cclxxx	−·986	−·167	+1·51	+0·26	−·154	−·212	= −0·89
f	cclxxxi	−·395	−·919	+0·59	+1·38	−·053	−·383	= −0·65
k	cclxxxii	−·946	+·324	+1·40	−0·48	−·134	−·565	= −1·02
γ	cclxxxiii	·810	+·586	−1·18	−0·86	+·099	−·649	= −0·06

Morning Observations, Sept. 7.

e	cclxxxvi	·995	Δ*a* +·096	Δδ −1·02	*a* −0·10	*b* −·103	*n* −·473	*z* = 0·54
g	cclxxxvii	−·985	−·171	+0·99	+0·17	+·115	−·234	= −1·14

Evening Observations, Sept. 8.

h	ccxc	−1·000	Δ*a* −·005	Δδ −·092	*a* −0·00	*b* −·216	*n* −·501	*z* = −0·89
e	ccxci	·998	+·070	+1·01	+0·07	+·191	−·400	= −0·20
g	ccxcii	−·982	−·187	−1·01	−0·19	−·182	−·307	= −0·45
g	ccxciii	−·982	−·187	−1·03	−0·20	−·177	−·308	= −0·33
e	ccxciv	·998	+·069	+1·07	+0·07	+·170	−·398	= −0·15
h	ccxcv	−1·000	−·008	−1·09	−0·00	−·162	−·507	= −0·19
e	ccxcvi	·998	+·068	+1·12	+0·08	+·152	−·396	= +0·42

Morning Observations, Sept. 8.*

d	ccxcvii	·736	Δ*a* −·677	Δδ +1·13	*a* −1·04	*b* −·041	*n* −·694	*z* = 1·40
k	ccxcviii	−·972	+·235	−1·54	+0·37	+·086	−·666	= −1·76
γ	ccxcix	·759	+·651	+1·21	+1·04	−·088	−·544	= 0·03
f	ccc	−·577	−·817	−0·94	−1·33	+·078	−·463	= −0·55
e	ccci	·998	+·060	+1·66	+0·10	−·132	−·374	= 0·47
g	cccii	−·982	−·188	−·165	−0·32	+·141	−·332	= −0·54
h	ccciii	−·999	−·017	−1·70	−0·03	+·151	−·532	= 0·00
e	cccv	·998	+·058	+1·84	+0·11	−·201	−·366	*z′* = 1·18
h	cccvi	−1·000	−·019	−1·87	−0·04	+·209	−·539	*z′* = −0·38

* There was a long interval between the observations ccciii and cccv, an interruption by clouds; it was thought best to suppose that the scale value might have changed in the interval, hence the term z' as distinguished from z.

Evening Observations, Sept. 9.

Star of Comp.	Rotation Number.								
e	cccvii	1·000	Δα + ·021	Δδ + 3·66	*a* + 0·08	*b* + ·182	*n* − ·304	*ε* =	*u* 0·69
q	cccviii	− ·981	− ·195	− 3·61	− ·72	− ·168	− ·405	=	− 1·40

Morning Observations, Sept. 9.

d	cccix	·645	Δα − ·765	Δδ + 2·72	*a* − 3·22	*b* − ·056	*n* − ·642	*ε* =	1·70
θ	cccx	− ·440	+ ·898	− 1·87	+ 3·82	+ ·042	− ·639	=	− 0·93
g	cccxi	− ·981	− ·194	− 4·20	− 0·83	+ ·131	− ·430	=	− 0·58
e	cccxii	1·000	+ ·004	+ 4·34	+ 0·02	− ·159	− ·276	=	0·96
e	cccxiii	1·000	+ ·003	+ 4·38	+ 0·01	− ·176	− ·274	=	0·94
g	cccxiv	− ·981	− ·194	− 4·34	− 0·86	+ ·187	− ·436	=	− 0·89
g	cccxv	− ·981	− ·194	− 4·37	− 0·86	+ ·195	− ·437	=	− 1·10
e	cccxvi	1·000	+ ·001	+ 4·47	+ 0·00	− ·206	− ·271	=	0·93
g	cccxvii	− ·981	− ·194	− 4·40	− 0·87	+ ·206	− ·439	=	− 1·09
e	cccxviii	1·000	+ ·000	+ 4·52	+ 0·00	− ·217	− ·269	=	0·95

Evening Observations, Sept. 10.

e	cccxix	·998	Δα − ·063	Δδ + 6·24	*a* − 0·39	*b* + ·186	*n* − ·211	*ε* =	0·58
g	cccxx	− ·980	− ·197	− 6·14	− 1·24	− ·174	− ·500	=	− 0·48
g	cccxxi	− ·980	− ·197	− 6·16	− 1·24	− ·167	− ·501	=	0·16
e	cccxxii	·998	− ·066	+ 6·31	− 0·42	+ ·161	− ·208	=	0·33
θ	cccxxiii	− ·535	+ ·845	− 3·39	+ 5·36	− ·086	− ·662	=	− 0·78
d	cccxxv	·554	− ·832	− 3·53	− 5·31	+ ·081	− ·610	=	0·74
f	cccxxvi	− ·725	− ·689	− 4·64	− 4·41	− ·080	− ·603	=	0·21
γ	cccxxvii	·607	+ ·795	+ 3·90	+ 5·11	+ ·056	− ·398	=	− 0·76

Morning Observations, Sept. 10.

e	cccxxix	·995	Δα − ·098	Δδ + 6·88	*a* − 0·68	*b* − ·146	*n* − ·184	*ε* =	1·06
g	cccxxx	− ·981	− ·196	− 6·81	− 1·36	+ ·157	− ·528	=	− 1·0
g	cccxxxi	− ·981	− ·196	− 6·83	− 1·36	+ ·167	− ·529	=	− 0·5
e	cccxxxii	·995	− ·103	+ 6·96	− 0·72	− ·181	− ·181	=	0·97
e	cccxxxiii	·995	− ·104	+ 6·98	− 0·73	− ·189	− ·180	=	1·39
g	cccxxxiv	− ·981	− ·196	− 6·91	− 1·38	+ ·192	− ·532	=	− 0·57
g	cccxxxv	− ·981	− ·195	− 6·93	− 1·38	+ ·198	− ·533	=	− 0·37
e	cccxxxvi	·994	− ·108	+ 7·04	− 0·76	− ·210	− ·178	=	0·84

Evening Observations, Sept. 11.

	cccxxxvii	·970	Δα − ·243	Δδ + 8·46	*a* − 2·12	*b* + ·207	*n* − ·126	*ε* =	0·1
	[illegible]	− ·981	− ·196	+ 8·57	− 1·71	− ·210	− ·590	=	− 0·45

Star of Comp.	Rotation Number.							
								n
g	cccxxxix	−·981	−·196	−8·59	−1·72	−·206	−·591	= −0·28
μ	cccxl	·965	+·263	+8·47	+2·31	+·196	−·389	= 0·39
μ	cccxli	·965	+·263	+8·49	+2·31	+·189	−·389	= −0·03
g	cccxlii	−·981	−·196	−8·66	−1·73	−·183	−·594	= −0·47
ϵ	cccxliii	·965	−·262	+8·55	−2·32	+·168	−·121	= 0·38

Since the errors of the star places are small as compared with the probable error of observation, and since nearly the same stars are observed in the evening and morning, we may assume that the star places are absolutely known.

There might be certain advantages in taking only pairs of observations in which the same stars are observed evening and morning, but this course necessarily involves the sacrifice of many observations. The observer, of course, always endeavours to employ the same stars in the evening and morning, but bad weather may come and he is only able to secure a portion of the observations. If he misses observations of certain stars on one evening, he endeavours to secure them on the next, and so on. Thus whilst upon the whole he can preserve a fair balance of evening and morning observations in which the same stars are employed, it is quite impossible to get a series of pairs of evening and morning observations of nearly equal weight, in which exactly the same stars have been used.

There is also always something arbitrary in obtaining the final result from such pairs of observations, a feeling that many good observations have been rejected for no sufficient reason, and the sacrifice of the advantage which the simultaneous treatment of all the observations offers, in determining the errors of the Tables and detecting outstanding observations.

The kind and energetic co-operation of so many observatories enables me to assign, even now, places of the stars whose probable error does not exceed $\frac{1}{10}$ of a second of arc, and when I have received the additional series which I expect, and these have been incorporated with the heliometric triangulation, I believe the probable error of each star's place will prove to be not greater than $\pm$ 0″·05.

These are the reasons which guided me to the decision that the final discussion must he made in the way I have described; and that decision once arrived at, all the equations admit of only one solution.

The following are the successive steps:—

I. From each group of equations normal equations must be formed, by the ordinary method of least squares, for each of the unknown quantities

$$\Delta\alpha,\ \Delta\delta,\ a,\ b,\ n,\ s.$$

II. Since z (which expresses the error of the assumed scale value) cannot be considered the same in each group, it is necessary to eliminate it before combining the various groups.

When three or more stars surrounding the planet have been observed, the elimination of z can of course be rigidly accomplished.

When only two stars have been observed (unless the planet is exactly in the line joining the stars), of course the data are wanting for projecting the planet on the line joining the stars. In such a case, however, everything represented by the observations will be obtained by multiplying the coefficient of z in the normal equation in z by such a number as will make it equal to the coefficient of z in the normal for $\Delta\alpha$, and then subtracting the equation so found from the normal in $\Delta\alpha$—eliminating, in fact, z from the normal in $\Delta\alpha$. Similarly z is to be eliminated from the other normals. In fact, in all cases, whatever the number of stars observed, this is the only admissible method of eliminating z, as it does not affect the determination of weight.

When only one star has been observed, the elimination of z is of course impossible without further data. On the morning of September 5 *Mars* was so near to the star g, and so favourably situated as to position angle (280°), that in order to secure a weighty result, this star alone was observed, but in the middle of the observations the distance between the stars e and g was measured and found to be

$$\overset{r}{274{\cdot}2184}.$$

or, converted into arc by our adopted screw value,

$$\overset{''}{7054{\cdot}89} + 0{\cdot}705\, z.$$

The tabular apparent distance of the stars e–g was

$$\overset{''}{7054{\cdot}84},$$

whence

$$7054{\cdot}89 + 0{\cdot}705\, z = 7054{\cdot}84,$$

or

$$z = -0{\cdot}28.$$

And this value of z was substituted in the normal equation for $\Delta\alpha$, $\Delta\delta$, a, b, and n, for September 5, morning observations.

III. The various values of z having been eliminated by the above methods from the normal equations, all the normals in $\Delta\alpha$ were added together, and similarly all the normals in $\Delta\delta$, a, b, and n, and so the final five normal equations were obtained:—

81·4	$\Delta\alpha$ − 1·88	$\Delta\delta$ − 3·09	a + 39·6	b + 1·43	n =	81·42,
− 1·89	+ 17·5	+ 40·2	− 45·3	+ 0·01	= −	9·20,
− 4·00	+ 40·2	+ 2440·0	− 220·0	+ 6·01	= −	176·3,
40·3	− 45·3	− 220·	+ 721·	+ 2·93	=	80·76,
1·44	+ 0·12	+ 6·03	+ 2·93	+ 2·38	=	0·686.

The solution of these gives the following values:—

	′	Weight.
$\Delta\alpha =$	0·993	78·7
$\Delta\delta =$	− ·203	14·3
$a =$	− ·0628	2500·
$b =$	·0277	589·
$n =$	− ·761	2·33.

When these values are substituted in the original equations together with value of z which results from the substitution of these values in the normal for z, the following are the residuals:—

Star of Comp.	Rotation Number.	″
	Evening, Sept. 4.	
f	ccxxix	−0·08
k	ccxxx	− ·17
g	ccxxxi	+ ·40
g	ccxxxii	− ·80
g	ccxxxiii	− ·57
g	ccxxxiv	+ ·54
k	ccxxxv	+ ·17
f	ccxxxvi	+ ·21
	Evening, Sept. 5.	
f	ccxxxix	−0·43
h	ccxl	+ ·29
g	ccxli	+ ·60
g	ccxlii	+ ·63
g	ccxliii	+ ·41
g	ccxliv	+ ·41
g	ccxlv	+ ·65
g	ccxlvi	+ ·31
	Morning, Sept. 5.	
g	ccxlvii	−0·05
g	ccxlviii	+ ·02
g	ccxlix	− ·24
g	ccl	+ ·57
g	ccli	+ ·56
g	cclii	+ ·20
g	ccliv	+ ·32
g	cclv	− ·40
g	cclvi	+ ·07
g	cclvii	− ·63
g	cclviii	− ·10
g	cclix	− ·25
	Evening, Sept. 6.	
f	cclx	−0·82
g	cclxi	+ ·52
g	cclxii	− ·86
e	cclxiii	+ ·24
e	cclxiv	+ ·94
h	cclxv	− ·01
g	cclxvi	− ·39
g	cclxvii	− ·46
f	cclxviii	− ·54
f	cclxix	− ·27
	Morning, Sept. 6.	
g	cclxx	+0·41
e	cclxxi	+ ·09
e	cclxxii	− ·08
h	cclxxiii	+ ·01
g	cclxxiv	+ ·42
	Evening, Sept. 7.	
h	cclxxvi	−0·65
e	cclxxvii	+ ·06
e	cclxxviii	− ·20
g	cclxxix	+ ·31
g	cclxxx	− ·11
f	cclxxxi	+ ·33
k	cclxxxii	− ·22
γ	cclxxxiii	− ·45

Star of Comp.	Rotation Number.	"
	Morning, Sept. 7.	
e	cclxxxvi	+0·09
g	cclxxxvii	− ·18
	Evening, Sept. 8.	
h	ccxc	−0·07
e	ccxci	+ ·82
g	ccxcii	− ·40
g	ccxciii	− ·53
e	ccxciv	+ ·78
h	ccxcv	− ·80
e	ccxcvi	+ ·22
	Morning, Sept. 8.	
d	ccxcvii	−0·60
k	ccxcviii	+ ·79
γ	ccxcix	+ ·61
f	ccc	+ ·10
e	ccci	+ ·51
g	cccii	− ·38
h	ccciii	−1·00
e	cccv	+0·19
h	cccvi	− ·13
	Evening, Sept. 9.	
e	cccvii	−0·43
g	cccviii	+ ·31
	Morning, Sept. 9.	
d	cccix	−1·01
θ	cccx	+0·61
g	cccxi	− ·14
e	cccxii	− ·07
e	cccxiii	− ·04
g	cccxiv	+ ·14
g	cccxv	+ ·34
e	cccxvi	− ·01
g	cccxvii	+ ·33
e	cccxviii	− ·03
	Evening, Sept. 10.	
e	cccxix	−0·13
g	cccxx	+ ·14
g	cccxxi	− ·63
e	cccxxii	+ ·14
θ	cccxxiii	+ ·42
d	cccxxv	− ·47
f	cccxxvi	− ·16
γ	cccxxvii	+1·04
	Morning, Sept. 10.	
e	cccxxix	−0·34
g	cccxxx	+ ·57
g	cccxxxi	− ·01
e	cccxxxii	− ·23
e	cccxxxiii	− ·64
g	cccxxxiv	+ ·04
g	cccxxxv	− ·16
e	cccxxxvi	− ·08
	Evening, Sept. 11.	
e	cccxxxvii	+0·06
g	cccxxxviii	+ ·05
g	cccxxxix	− ·12
μ	cccxl	− ·18
μ	cccxli	+ ·25
g	cccxlii	+ ·05
e	cccxliii	− ·12

From these residuals the probable error of one observation, including the error of the heliometer measure and the error of the star's place, is

$$\pm 0''.302.$$

With this probable error we now find the probable error of the various results

$$= \frac{\text{probable error}}{\sqrt{\text{weight}}},$$

and we have

$\Delta\alpha =$	$0''\cdot993$	$\pm 0''\cdot034$,
$\Delta\delta =$	$-\ ''\cdot203$	$\pm 0''\cdot080$,
$a =$	$-\ ''\cdot0628$	$\pm 0''\cdot0060$,
$b =$	$''\cdot0277$	$\pm 0''\cdot0124$,
$\pi =$	$-\ ''\cdot761$ %	$\pm 0''\cdot198$ %,
or correction of assumed ⊙ parallax	$= -\ ''\cdot067$	$\pm\ ''\cdot0174$.

I would have preferred not to have communicated this result in its present form, but to have waited until it was possible to deduce the definitive result from all the observations.

I think I have sufficiently shown how very desirable it is to start in the final discussion with star places of the highest possible accuracy. That condition I can only secure by a complete and thorough discussion of all available material, including those interesting questions as to personality in R.A. observations to which I have referred in my previous paper. I can hardly receive the results of these special observations before the end of the year, and there remains besides the discussion of the triangulation, which is a long and tedious operation.

I am continually being pressed by the Fellows for results, and it is by the advice of the Astronomer Royal that I have given the report in its present form. It will, at least, enable the Fellows to see that no time has been lost; and I trust it may also be the means of prompting valuable criticism.

It appears that the probable error of one observation is not greater than, if so great as, that of an average transit of *Venus* contact observation, whilst the parallax factors are about the same. Thus a single observer, on a single clear night, can do as much for the determination of the solar parallax as nine or ten costly transit expeditions; the observations also possess one enormous advantage, that they are only capable of one interpretation.

I have rejected no complete observation between September 4 and 11, but during that period only a little more than one-fourth of the total number of observations were made. It would appear then that the final result will be one of very great accuracy if it is not affected by any systematic error.

I have not found it possible to conceive any form of systematic error to which the observations are liable; but on this point I most earnestly invite criticism and suggestion, either now or at a future time.

There is only one form of criticism which is useless, and it is one which is unfortunately too common, viz. that the result is right or wrong according as it agrees with the critic's preconceived notions as to what it should be. It is for this reason I have not published the value of the assumed parallax; and as all useful criticism can equally well be made without this information, I think it is better to defer the publication of any value of the parallax until the definitive result is arrived at.

On Newcomb's Correction to Hansen's Value of the Secular Acceleration. By E. Neison, Esq.

Prof. Newcomb, in his recent valuable researches on the motion of the Moon (*Washington Observations*, 1875, Appendix ii., 1878), by comparing Hansen's *Tables de la lune* with the observations of the eclipses recorded by the Alexandrian and Arabian astronomers, has shown that Hansen has assigned too great a value to the mean motion and secular acceleration of the Moon. Further, by comparing Hansen's tables with the early observations of the Moon made between 1600 and 1750, Prof. Newcomb shows that the tables entirely fail to represent these observations.

By diminishing the secular acceleration by $3''{\cdot}86$ and the secular mean motion by $29''{\cdot}17$, and by rejecting one of Hansen's terms of long period in accordance with Delaunay's researches, and by empirically diminishing by 60° the constant part of the argument of the other, it is possible, as Prof. Newcomb shows, to make Hansen's tables closely represent the motion of the Moon for the whole period, 1625–1875, and very much improve the manner with which they represent the eclipses recorded by the Arabian and Alexandrian astronomers. In this manner Prof. Newcomb obtains $8''{\cdot}31$ for the value of the secular acceleration of the mean motion which is indicated by observations, a much closer approximation to the theoretical value, $6''{\cdot}18$, than had hitherto been obtained.

Apart from other considerations this result is of very considerable importance, because it throws much doubt on the supposed tidal retardation of the rotation of the Earth, an hypothesis which has given rise to much speculation, though it has not yet been proved to be possible for the terrestrial tides to produce a secular retardation of the rotation of the Earth.

I wish to show that there is one point in Prof. Newcomb's researches which he seems to have overlooked, and that is, that the value which he assigns to the diminution in Hansen's secular acceleration depends almost entirely on the weight to be assigned to a single eclipse in the numerous series employed by him; so that, by rejecting this eclipse, or by assigning to it a different weight, very great modifications will be introduced

into the amount by which Hansen's secular acceleration is to be corrected.

The principal data employed by Prof. Newcomb are thirteen eclipses of the Moon of which observations are recorded by Ptolemy, and twenty-two eclipses of the Sun and Moon observed by the Arabian astronomers between 820 and 1004. From these observations, united into groups, Prof. Newcomb derives the following corrections to Hansen's tables:—

Obs.	Epoch.		Weight.	Obs.	Epoch.		Weight.
(3)	$-687.\delta\zeta = -11'$	$\pm 4'$	3,				
(3)	$-381.$ " $= -27'$	$\pm 5'$	2,	(3)	$850.\delta\zeta = -3'8$	$\pm 2'4$	8,
(8)	$-189.$ " $= -20'$	$\pm 3'$	4,	(7)	$927.$ " $= -1'6$	$\pm 1'7$	16,
(3)	$+137.$ " $= -16'$	$\pm 4'$	3.	(20)	$986.$ " $= -4'5$	$\pm 1'3$	30.

After correcting Hansen's value of the secular acceleration and mean motion, the tables represent these observations with the following residuals.

Epoch.		Epoch.	
-687	$= +17'$,		
-381	$= -7'$,	850	$= -2'8$,
-189	$= -4'$,	927	$= -0'9$,
$+137$	$= -6'$.	986	$= -4'2$.

It is obvious that the tables, even when amended, do not satisfactorily represent the observations of these eclipses, since (with a single exception) all the errors tend in one direction. It is in fact impossible to represent the first group of eclipses (mean epoch $= -687$), without introducing enormous discordances in the others; but if this group be rejected, all the others can be well represented. This discordant group of eclipses consists of four, as follows:—

-720	March	19	$\delta\zeta = -4' \pm 6'$,
-711	March	8	" $= -36' \pm 22'$,
-711	September	1	" $= -22' \pm 11'$,
-620	April	21	" $= -23' \pm 11'$.

Prof. Newcomb rejects the second of these, because it is not specially stated whether the beginning or middle of the eclipse was observed, and combines the other three by assigning to them the weights 3, 1, 2 respectively. The first eclipse has therefore a very preponderating weight attached to it. It is evident, however, that this eclipse is entirely discordant, for it indicates a very small positive correction, whereas all the others retained by Newcomb show very much larger corrections. The mean of the two other eclipses is $-23'$, and the mean of all four $-21'$. By giving this high weight to this one eclipse Prof. Newcomb has rendered its importance so great that it almost overbalances all the others, not only in this group but in all the others.

If this single discordant eclipse be rejected, but in all other respects the data employed by Prof. Newcomb be retained, whilst the other corrections remain sensibly unaltered, the value of the correction to the secular acceleration rises from $-3''{\cdot}81$ to $-4''{\cdot}80$. As Prof. Newcomb regards the two other eclipses as doubtful, it seems more satisfactory to reject the entire group, and solve the equations without them. In this way, whilst the correction to the epoch and mean motion remain almost entirely unchanged, the correction to the secular acceleration becomes $-4''{\cdot}97$ instead of $-3''{\cdot}81$. In this way the ancient eclipses are far better represented, the residuals being

$$-381 = +2'{\cdot}4 \qquad 850 = -0'{\cdot}8,$$
$$-189 = +3'{\cdot}9 \qquad 927 = +0'{\cdot}6,$$
$$+134 = -0'{\cdot}2 \qquad 986 = -2'{\cdot}8.$$

The rejected group is

Obs.	Epoch.	Weight.	
(2)	$-660, \delta\zeta = -23 \pm 9$	1,	residual $= +15'$

The observations between 1625 and 1875 are still better represented by this value than by that employed by Prof. Newcomb. The result shows that Hansen's value of the secular acceleration can be reduced to as low as $7''{\cdot}20$ or only a single second greater than the theoretical value, $6''{\cdot}18$.

When the Arabian observations of eclipses and the modern observations between 1625 and 1875 are considered alone, they are best represented by the theoretical value of the secular acceleration. Thus, by diminishing Hansen's mean motion by $30''$ per century, and his secular acceleration by $6''$, so as to obtain the theoretical value, the tables as amended represent not only the observations between 1625 and 1875, but also the Arabian observations, the residuals being

$$\left.\begin{aligned} 850 &= +0'{\cdot}6 \\ 927 &= +1'{\cdot}6 \\ 986 &= -1'{\cdot}9 \end{aligned}\right\} = -0'{\cdot}7.$$

Even the ancient observations are represented as well as by Prof. Newcomb's correction, the residuals being

$$-660 = +17',$$
$$-381 = +\ 7',$$
$$-189 = +\ 7',$$
$$-134 = +\ 3'.$$

These results render very problematical the existence of any tidal retardation in the rotation of the Earth, by showing that it is possible to tolerably well represent the motion of the Moon with only the theoretical value of the secular acceleration.

It is remarkable that the ancient eclipses should uniformly indicate a greater value for the secular acceleration than the Arabian observations. In fact, to reconcile the two it is essential to suppose that there exists a term of very long period in the Moon's longitude. A term with a period of two or three thousand years—and it has been already shown that terms of this period exist—and a coefficient only three or four times larger than that of Hansen's term would completely reconcile the two classes of observations.

Observations of the Periodic Comet of Tempel, 1878.
By Prof. C. Pritchard.

Oxford Mean Time of Observation.	Apparent R.A. of Comet.	Log Factor of Parallax in R.A.	Apparent N.P.D. of Comet.	Log Factor of Parallax in N.P.D.	Star of Comparison.
h m s	h m s		° ′ ″		
July 27 10 40 25·8	15 26 2·29	8·5287	97 29 57·7	9·9150	*a*
„ 28 11 10 2·5	15 27 26·01	8·5564	97 55 46·9	9·9125	*b*
„ 31 10 8 42·3	15 31 52·86	8·4972	99 14 28·5	9·9228	*c*
„ 31 10 11 47·7	15 31 52·93	8·5023	99 14 26·7	9·9224	*c*
Aug. 1 10 10 31·5	* 4 18·63	8·5069	* 5 6·3	7·9230	

The assumed mean positions of the stars for January 1, 1878, are

	h m s	° ′ ″
a	15 26 33·85	97 40 8·7
b	15 28 11·06	97 31 20·9
c	15 32 55·37	99 11 17·8

The Comet resembled a faint round nebula of about 1′ in diameter. The condensation was very slight, and the observations refer to the centre of the nebulosity. The observation on July 28 is very uncertain, unfavourable atmospheric circumstances rendering the comet very faint. The second observation on July 31 was made by Mr. Jenkins. The star of comparison on August 1 has not been found in any Catalogue. The observations were made with the Grubb 12¼-inch refractor, by the first assistant, Mr. W. Plummer.

Observation of Encke's Comet. By J. Tebbutt, Esq.

With the help of Dr. von Asten's Ephemeris, in No. 2197 of the *Astronomische Nachrichten*, I succeeded in finding Encke's Comet on the evening of the 3rd instant. It presented the appearance of a small round nebula gradually condensed towards the centre, and was within a few minutes of arc of the position

assigned to it in the Ephemeris. I had not time to get a comparison observation. The following night was very cloudy, and the comet could not therefore be observed. On the evening of the 5th, however, I obtained four comparisons with Lalande 20142, which give the following position for the comet :—

Aug. 5^d 6^h 29^m 44^s Windsor M.T. { App. R.A. = 10^h 16^m $14^s.2$ / App. N.P.D. = 83° 42′ 31″

It has been observed on every evening since the 5th, but on the 11th, 12th, and 13th it was excessively faint owing to the increased moonlight. I will forward the observations to the Society when they are completed and reduced. I avail myself of this opportunity to state that I have on several occasions searched for Tempel's comet II. 1873, in the rough positions given in *Nature* of the 21st of March last, but in vain.

Observatory, Windsor, N. S. Wales,
August 14, 1878.

Double Star Observations made in 1877–8 *at Chicago with the* 18½*-inch Refractor of the Dearborn Observatory, comprising, I. A Catalogue of* 251 *Double Stars; II. Micrometrical Measures of* 500 *Double Stars.* By S. W. Burnham, Esq.

(*Abstract.*)*

The astronomical observations contained in the paper were made between July 22, 1877, and October 15, 1878. The new double stars are numbered consecutively with those in the author's former Catalogues published as follows :—

First Catalogue	Nos. 1 to 81	*Monthly Notices R.A.S.*,	March 1873.
Second ,,	82 ,, 106	,, ,,	May 1873.
Third ,,	107 ,, 182	,, ,,	Dec. 1873.
Fourth ,,	183 ,, 229	,, ,,	June 1874.
Fifth ,,	230 ,, 300	,, ,,	Nov. 1874.
Sixth ,,	301 ,, 390	*Astron. Nach.*, No. 2062.	
Seventh ,,	391 ,, 436	,, 2103.	
Eighth ,,	437 ,, 452	*American Jour. of Science*,	July 1877.
Ninth ,,	453 ,, 482	*Monthly Notices R.A.S.*,	Dec. 1877.

The present work forms the tenth Catalogue of the series and extends the number of new pairs to 733. Of the 251 pairs in this list, 75 pairs are from 0″ to 1″ in distance, and 59 pairs from 1″ to 2″.

* The Paper will be published *in extenso* in the volume of *Memoirs*.—Ed.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXIX. *December* 13, 1878. No. 2.

Lord LINDSAY, M.P., F.R.S., President, in the Chair.

The Rev. Charles Heaven, M.A., The Orchards, Stone, Aylesbury; and
James Whewall, Esq., Savile House Observatory, Halifax;

were balloted for and duly elected Fellows of the Society.

On the Law of Force to any Point in the Plane of Motion, in order that the Orbit may be always a Conic.

By J. W. L. Glaisher, M.A., F.R.S.

§ 1. In a paper "Sur la possibilité de déduire d'une seule des lois de Kepler le principe de l'attraction," printed in the *Comptes Rendus*, t. 84, pp. 671–674 (April 9, 1877), M. Bertrand remarks that it would be interesting to solve the following problem: "En sachant que les planètes décrivent des sections coniques, et sans rien supposer de plus, trouver l'expression des composantes de la force qui les sollicite, exprimées en fonction des coordonnées de son point d'application," and adds, "Nous connaissons deux solutions: La force peut-être dirigée vers un centre fixe et agir proportionnellement à la distance, ou en raison inverse de son carré. En existe-t-il d'autres?"

The problem was completely solved by M. Darboux (*Comptes Rendus*, t. 84, pp. 760–762 and 936–938, April 16 and 30), and M. Halphen (*Ibid.*, pp. 939–941), who each proved that a body moving in the plane of xy under the action of a central force, equal to either

$$\frac{\mu r}{(ax+by+c)^n} \quad \ldots\ldots\ldots \quad (1)$$

or

$$\frac{\mu r}{(ax^2+bxy+cy^2)^{\frac{5}{2}}} \quad \ldots\ldots\ldots\ldots \quad (2)$$

must describe a conic whatever be the initial conditions of the motion, and that there are no other laws of force for which this is true.

It is also shown that all the conics described under the action of the law (1) have $ax+by+c=0$ as polar of the origin, and those described under the action of (2) have $ax^2+bxy+cy^2=0$ as tangents (real or imaginary).

M. Darboux obtained his results by substituting the value of u given by the general equation of a conic,

$$u = a\cos\theta + b\sin\theta + \sqrt{(\mathrm{A}\cos 2\theta + \mathrm{B}\sin 2\theta + \mathrm{H})},$$

in the differential equation

$$\frac{d^2u}{d\theta^2} + u = \frac{\mathrm{P}}{h^2u^2};$$

while M. Halphen's process, which is very elegant, depends upon the differential equation of the fifth order satisfied by conics.

If the motion is not restricted to take place in the plane of xy, the laws of force are

$$\frac{\mu r}{(ax+by+cz+d)^3}$$

and

$$\frac{\mu r}{(ax^2+a'y^2+a''z^2+2byz+2b'zx+2b''xy)^{\frac{5}{2}}};$$

and, as remarked by M. Halphen, in the former case all the polars of the centre of force with regard to the conics lie in the plane $ax+by+cz+d=0$, and in the latter case all the conics have double contact with the cone

$$ax^2+a'y^2+a''z^2+2byz+2b'zx+2b''xy=0.$$

In what follows I shall, for the sake of simplicity, only consider motion in the plane of xy; it is evident that the extension to the case of motion in three dimensions presents no difficulty.

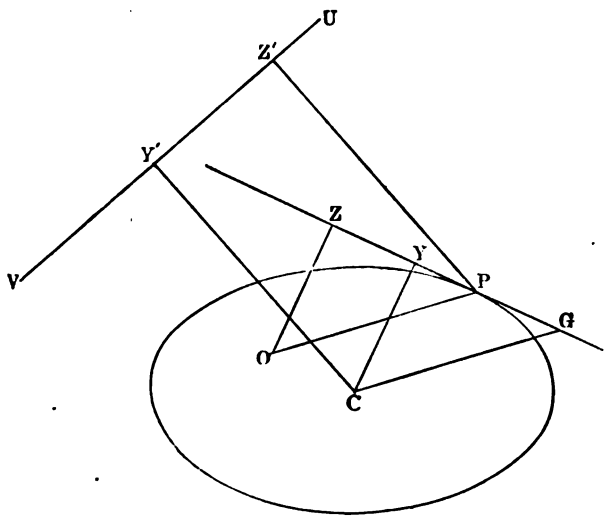
§ 2. Newton, in the scholium to Prop. xvii. of the *Principia*, finds the law of force tending to any point in order that any given conic may be described about it; and I now proceed to consider the expression for the force given by Newton, and to connect it with the results obtained by MM. Darboux and Halphen.

The law of force in the scholium to Prop. xvii. is deduced by Newton from Corollary 3 to Prop. vii., in which it is shown that the force under the action of which a body P revolves in any

orbit about any centre of force C is to the force under the action of which it can revolve in the same orbit in the same periodic time about any other centre of force O as $OP^2 . CP$ to CG^3, CG being drawn parallel to OP and cutting the tangent at P in G.

Now let C be the centre of the conic, so that the law of force is μr; then (fig. 1)

Fig. 1.



$$\frac{\text{force to O}}{\text{force to C}} = \frac{CG^3}{OP^2 . CP},$$

therefore

$$\text{force to O} = \mu \left(\frac{CG}{OP}\right)^3 OP,$$

which is the law of force given in the scholium to Prop. xvii.

If CY and OZ are the perpendiculars let fall upon the tangent at P, we see that

$$\text{force to O} = \mu \left(\frac{CY}{OZ}\right)^3 OP.$$

Now if UV is the polar of O, and CY′, PZ′ are perpendiculars let fall upon it,

$$\frac{CY}{OZ} = \frac{CY'}{PZ'} \quad \ldots\ldots\ldots \quad (3)$$

so that

$$\text{force to O} = \mu \left(\frac{CY'}{PZ'}\right)^3 OP$$

$$= \mu \left(\frac{p_o}{p}\right)^3 r,$$

p and p_o denoting the perpendiculars from P and the centre upon the polar of O.

Thus any conic may be described under the action of a force $\frac{\mu r}{p^3}$ tending to O; and since the periodic time is the same for the force μr to C and $\mu \left(\frac{p_o}{p}\right)^3 r$ to O, it is equal to $\frac{2\pi}{\sqrt{\mu}}$; and therefore when the force is $\frac{\mu r}{p^3}$, the periodic time is $\frac{2\pi}{\sqrt{\mu}} p_o^{\frac{3}{2}}$.

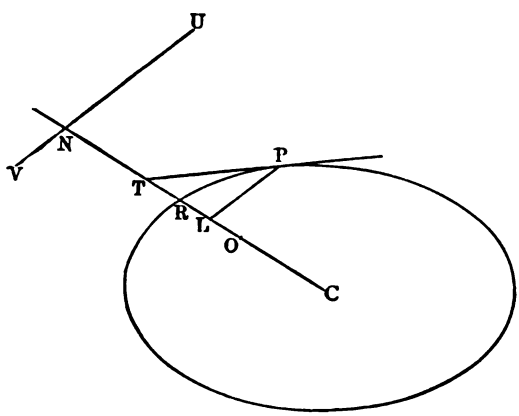
In the case of the parabola the centre passes to infinity, so that p_o is infinite; but if we diminish μ so that $\mu p_o^3 = \mu'$, the force to O is still $\frac{\mu' r}{p^3}$, the extension to the case of the parabola being similar to that in the scholium to Prop. x. of the *Principia*. But the law of force to any point O of a parabola can be deduced directly from that to the focus without difficulty. This is done in § 5.

§ 3. The equation (3), viz. that

$$\frac{CY}{OZ} = \frac{CY'}{PZ'},$$

is easily proved geometrically, for if PL (fig. 2) be drawn parallel to the polar UV, then

Fig. 2.



$$\frac{\text{perpendicular from O on tangent at P}}{\text{perpendicular from C on tangent at P}} = \frac{OT}{CT},$$

$$\frac{\text{perpendicular from P on polar of O}}{\text{perpendicular from C on polar of O}} = \frac{LN}{CN},$$

and

$$\frac{OT}{CT} = \frac{LN}{CN},$$

for

$$CO \cdot CN = CR^2 = CL \cdot CT,$$

giving

$$\frac{CO}{CT} = \frac{CL}{CN};$$

and therefore

$$\frac{CT - CO}{CT} = \frac{CN - CL}{CN},$$

that is

$$\frac{OT}{CT} = \frac{LN}{CN};$$

but the proposition is evident at once analytically, for if $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$ be the equation of the ellipse, and if h, k be the point O, x, y the point P, then

$$\frac{OZ}{CY} = \frac{hx}{a^2} + \frac{ky}{b^2} - 1 = \frac{PZ'}{CY'}.$$

It may be observed that (3) is only a particular case of a more general proposition in which P and the tangent at P may be replaced by any point P and its polar; for let the coordinates of O and P be h, k and h', k', then

$$\frac{\text{perpendicular from P on polar of O}}{\text{perpendicular from centre on polar of O}} = \frac{hh'}{a^2} + \frac{kk'}{b^2} - 1$$

$$= \frac{\text{perpendicular from O on polar of P}}{\text{perpendicular from centre on polar of P}}.$$

This proposition is proved for circles in Salmon's *Conics*, 5th edition, Art. 101, p. 93.

§ 4. The law of force in the Newtonian form $\mu \left(\frac{CY}{OZ}\right)^3 OP$ leads directly to the analytical expressions for the force in terms of the coordinates of any point; for let the point O be the origin, and suppose that the conic

$$ax^2 + 2hxy + by^2 + 2gx + 2fy + c = 0$$

is described about O. The tangent at x, y is

$$ax\xi + h(x\eta + y\xi) + by\eta + g(x + \xi) + f(y + \eta) + c = 0;$$

and, x_0, y_0 being the coordinates of the centre,

$$\frac{CY}{OZ} = \frac{ax_0 + h(xy_0 + yx_0) + byy_0 + g(x + x_0) + f(y + y_0) + c}{gx + fy + c},$$

where x_o, y_o are given by the equations

$$ax_o + hy_o + g = 0,$$

$$hx_o + by_o + f = 0.$$

Multiplying these equations respectively by x and y, and subtracting them from the numerator of the expression for $\frac{CY}{OZ}$, we have

$$\frac{CY}{OZ} = \frac{gx_o + fy_o + c}{gx + fy + c},$$

and therefore

$$\text{force to O} = \mu\left(\frac{CY}{OZ}\right)^3 OP = \mu\left(\frac{gx_o + fy_o + c}{gx + fy + c}\right)^3 r$$

$$= \frac{\mu' r}{(gx + fy + c)^3}.$$

§ 5. Consider the case of the parabola separately. The force to the focus S is $\frac{\mu}{SP^2}$, and therefore

$$\text{force to any point O} = \left(\frac{Sg^2}{OP^2 . SP}\right)\frac{\mu}{SP^2} = \mu\left(\frac{Sg}{OP . SP}\right)^3 OP$$

$$= \mu\left(\frac{Sy}{OZ . SP}\right)^3 OP,$$

where Sg is drawn parallel to OP cutting the tangent at P in g, and Sy is the perpendicular upon the tangent at P.

Now $\frac{Sy}{SP} = \sin\theta$, where θ is the inclination of the tangent at P to the axis of the parabola, and therefore

$$\text{force to O} = \mu\left(\frac{\sin\theta}{OZ}\right)^3 OP \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

$$= \mu\left(\frac{\sin\alpha}{PZ'}\right)^3 OP,$$

where PZ′ is the perpendicular upon the polar of O, and α is the inclination of the polar of O to the axis of the parabola. Thus the force to O $= \frac{\mu' r}{p^3}$ as before.

The theorem

$$\frac{OZ}{\sin\theta} = \frac{PZ'}{\sin\alpha}$$

is true when P and the tangent at P are replaced by any point P and the polar of P; viz. we have

$$\frac{\text{perpendicular from P on polar of O}}{\text{perpendicular from O on polar of P}} = \frac{\sin\alpha}{\sin\beta},$$

where α, β are the inclinations of the polars of O and P to the axis of the parabola.

Enunciated in a geometrical form, this theorem asserts that if O and P be any two points, and if OO′ be drawn parallel to the axis, cutting the polar of P in O′, and PP′ be drawn parallel to the axis, cutting the polar of O in P′, then OO′ = PP′. The proof is very simple; for, $y^2 = 4ax$ being the equation of the parabola and h, k the point O, h', k' the point P, then the equation of the polar of P is $yk' = 2a\,(x+h')$, and therefore

$$OO' = \frac{kk'}{2a} - h - h',$$

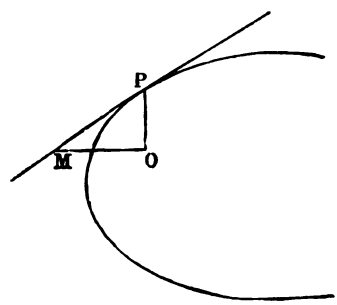
which involves the coordinates of O and P symmetrically.

The equation (4) gives a simple expression for the law of force to any point in a parabola; for if a body be describing a parabola under the action of a force tending to any point O, then we see from (4) that

$$\text{force to O} = \mu \frac{OP}{OM^2},$$

where OM is drawn parallel to the axis cutting the tangent at P in M (fig. 3).

Fig. 3.



§ 6. It follows therefore that under the action of the force

$$\frac{\mu r}{(ax+by+c)^5} \quad \ldots\ldots\ldots \quad (1)$$

any conic having $ax+by+c = 0$ as the polar of O may be described. Taking O as the origin, the general equation of all such conics is

$$(ax+by+c)^2 = Ax^2 + 2Hxy + By^2; \quad \ldots\ldots \quad (5)$$

and since, the line $ax+by+c = 0$ being given, this equation contains two arbitrary constants in addition to an arbitrary quantity λ by which a, b, c must admit of being multiplied in virtue of

the factor $\frac{\mu}{h^2}$ in the differential equation, it follows that this is the most general form of orbit that can be described under the action of the force (1). From (5) we see that the conic can be also described under the action of the force

$$\frac{\mu r}{(Ax^2+2Hxy+By^2)^{\frac{5}{2}}}; \quad \ldots\ldots\ldots \quad (2)$$

and, since $Ax^2+2Hxy+By^2=0$ being two given lines, the equation (5) contains two arbitrary constants besides the quantity λ by which A, B, C may be multiplied, it follows that, under the action of (2), the body will always describe a conic having $Ax^2+2Hxy+By^2=0$ as the (real or imaginary) tangents from the origin.

§ 7. There are no other laws of force for which the orbit is always a conic; for suppose that

$$\frac{\mu r}{\{\phi(x, y)\}^3}$$

expresses such a law, then

$$ax+by+c=\phi(x, y) \quad \ldots\ldots\ldots \quad (6)$$

must represent a conic of which $ax+by+c=0$ is the polar of the origin, and containing two arbitrary constants in addition to the constants in $\lambda\phi(x, y)$.

The most general rational equations of the form (6) for which $ax+by+c=0$ represents the polar of the origin are

$$ax+by+c = Ax^2+2Hxy+By^2+\nu(2ax+2by+c)+\tfrac{1}{2}c. \quad \ldots \quad (7)$$

$$(ax+by+c)^2 = Ax^2+2Hxy+By^2+\nu(2ax+2by+c) \quad \ldots \quad (8)$$

and it is not difficult to assure oneself, by examining the different cases and transformations, that the only transformation satisfying the requisite conditions is obtained by putting $\nu=0$ in (8), which then becomes identical with (5). M. Darboux gives a proof that (1) and (2) are the only laws, on pp. 936, 937 of his second paper in the *Comptes Rendus*.

From (7) we see that if the force be

$$\frac{\mu r}{(Ax^2+2Hxy+By^2+f)^{\frac{5}{2}}}$$

the body will describe a conic having its asymptotes parallel to the lines $Ax^2+2Hxy+By^2=0$ if properly projected.

It will be observed that the problem solved by Newton is, "Given any conic (or curve, the law of force for the description of which about any one point is known), find the law of force to

any point"; while M. Bertrand's problem is, "Find the general law of force, expressed in terms of x and y, such that the orbit is always a conic, whatever the initial conditions may be," and it is remarkable that there should be two distinct laws of force for which this is true.

§ 8. As far as I know, the pair of expressions (1) and (2) were first obtained by MM. Darboux and Halphen; but the law $\frac{\mu r}{p^3}$, which is identical with $\frac{\mu r}{(ax+by+c)^3}$, was discovered by Sir W. R. Hamilton, and is thus enunciated in the *Proceedings* of the Royal Irish Academy, No. 57, vol. iii., p. 308 (November 30, 1846).

"Sir William R. Hamilton stated the following theorems of central forces, which he had proved by his calculus of quaternions, but which, as he remarked, might be also deduced from principles more elementary. 'If a body be attracted to a fixed point, with a force which varies directly as the distance from that point and inversely as the cube of the distance from a fixed plane, the body will describe a conic section, of which the plane intersects the fixed plane in a straight line, which is the polar of the fixed point with respect to the conic section."

The second theorem, which is analogous to the first, relates to motion on a sphere in a spherical conic. The account then proceeds: "The first theorem had been suggested to Sir W. Hamilton by a recently resumed study of a part of Sir Isaac Newton's *Principia.*"

A short analytical proof of the converse of this theorem, viz. that "if X be any given conic, O any point in its plane, F a central force at O which causes a material particle to describe X, then F varies as $\frac{r}{p^3}$," was given by Professor Casey in a paper, "On M'Cullagh's property of a self-conjugate triangle and Sir W. Hamilton's law of force for a body describing a conic section" (*Quarterly Journal of Mathematics*, vol. v. (1862), pp. 233–235).

It thus appears that a reply to M. Bertrand's question with regard to the existence of other laws besides μr and $\frac{\mu}{r^2}$ for which the orbit was always a conic had been given by Sir W. R. Hamilton's theorem that the orbit is always a conic when the law of force is $\frac{\mu r}{p^3}$, p being the perpendicular on any fixed plane; but M. Bertrand's general problem seems never to have been considered. It is not unlikely that Sir W. R. Hamilton deduced his law from Newton's Prop. xvii., and it is curious that the general formulæ which are deducible from the translation of Newton's results into analysis should not have been examined.

§ 9. The elegant expression for the periodic time to which Newton's corollary leads, viz. that if a conic be described under

the action of the force $\frac{\mu r}{p^3}$ tending to a point O, then the periodic time is $\frac{2\pi}{\sqrt{\mu}} p_o^{\frac{3}{2}}$, where p_o is the perpendicular from the centre of the conic upon the polar of O, seems not to have been previously noticed. It is interesting to apply it to the cases in which O coincides with the centre and focus. If O coincides with the centre, then the polar is at infinity, so that $\frac{\mu}{p^3} = \frac{\mu}{p_o^3}$ = constant $= \mu'$ suppose: thus the force is $\mu' r$ and the periodic time is $\frac{2\pi}{\sqrt{\mu'}}$.

If O coincides with the focus, the polar is the directrix, so that $p = \frac{r}{e}$: thus the force is $\frac{\mu e^3}{r^2}$ and the periodic time is $\frac{2\pi}{\sqrt{\mu}} \left(\frac{a}{e}\right)^{\frac{3}{2}}$, that is, the force is $\frac{\mu'}{r^2}$ and the periodic time is $\frac{2\pi}{\sqrt{\mu'}} a^{\frac{3}{2}}$.

If p denotes, as in Sir W. R. Hamilton's theorem, the perpendicular upon a given fixed plane, the periodic time will be $\frac{2\pi}{\sqrt{\mu}} p_o^{\frac{3}{2}}$, p_o being the perpendicular from the centre upon the fixed plane; so that the periodic time in all orbits having their centres in a plane parallel to the fixed plane is the same. If the plane of motion be parallel to the fixed plane p is constant and we have the case of motion under the action of a force to the centre.

§ 10. By means of the formula $\frac{2\pi}{\sqrt{\mu}} p_o^{\frac{3}{2}}$ it will be found that if the conic

$$(ax + by + c)^2 = Ax^2 + 2Hxy + By^2$$

be described about the origin under the action of the force

$$\frac{\mu r}{(ax + by + c)^3}$$

or

$$\frac{\mu r}{(Ax^2 + 2Hxy + By^2)^{\frac{3}{2}}},$$

the periodic time will be

$$\frac{2\pi}{\sqrt{\mu}} (ax_o + by_o + c)^{\frac{3}{2}},$$

x_o, y_o being the coordinates of the centre,

$$= \frac{2\pi}{\sqrt{\mu}} \left\{ \frac{c\,(AB - H^2)}{AB - H^2 - (Ab^2 + Ba^2 - 2Hab)} \right\}^{\frac{3}{2}};$$

and that if the conic

$$ax^2 + 2hxy + by^2 + 2gx + 2fy + c = 0$$

be described about the origin under the action of the force

$$\frac{\mu r}{(gx+fy+c)^3},$$

or

$$\frac{\mu r}{\{(g^2-ac)\,x^2+2\,(fg-hc)\,xy+(f^2-bc)\,y^2\}^{\frac{3}{2}}},$$

the periodic time will be

$$\frac{2\pi}{\sqrt{\mu}}(gx_0+fy_0+c)^{\frac{3}{2}},$$

$$=\frac{2\pi}{\sqrt{\mu}}\left\{\frac{c\,(ab-h^2)-(af^2+bg^2-2hfg)}{ab-h^2}\right\}^{\frac{3}{2}},$$

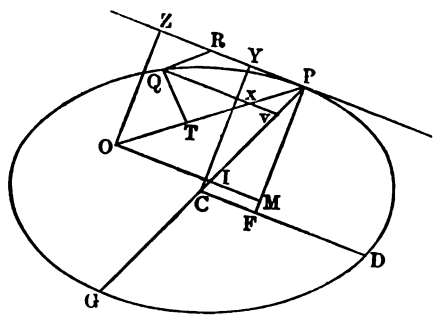
and the same expression will denote the periodic time if this orbit be described about the point p, q under the action of the force

$$\frac{\mu r}{\{apx+h\,(xq+yp)+bqy+g\,(x+p)+f\,(y+q)+c\}^3},$$

r being measured from p, q.

§ 11. The expression $\mu\left(\frac{CY}{OZ}\right)^3 OP$ for the force to any point O may be investigated directly in the same manner and with the same facility as the force to the focus is obtained by Newton in Prop. xi.; for if F denote the force to O, then (fig. 4)

Fig. 4.



$$F=\frac{2h^2}{OP^2}\cdot\frac{QR}{QT^2}.$$

By similar triangles QTx, PMO,

$$\frac{QT}{Qx}=\frac{PM}{OP},$$

and

$$\frac{Qv^2}{Pv.Gv}=\frac{CD^2}{CP^2}. \quad \ldots\ldots\ldots \quad (9)$$

Now

$$\frac{Pv}{QR} = \frac{Pv}{Px} = \frac{PI}{OP} = \frac{CP}{PF}\cdot\frac{PM}{OP};$$

therefore

$$\frac{Qv^2}{QR.Gv} = \frac{CD^2}{CP.PF}\cdot\frac{PM}{OP},$$

whence, since ultimately $Qx = Qv$, and by (9),

$$\frac{QT^2}{QR} = 2\frac{CD^2}{PF}\left(\frac{PM}{OP}\right)^3.$$

Thus

$$F = \frac{2h^2}{OP^2}\cdot\frac{1}{2}\frac{PF}{CD^2}\left(\frac{OP}{PM}\right)^3$$

$$= \frac{h^2}{a^2b^2}\left(\frac{PF}{PM}\right)^3 OP$$

$$= \frac{h^2}{a^2b^2}\left(\frac{CY}{OZ}\right)^3 OP.$$

Newton himself uses Corollary 3 of Prop. vii. in his second demonstration of Prop. xi. to deduce the law of force to the focus from that to the centre.

§ 12. The law of force

$$\frac{\mu r}{(Ax^2 + 2Hxy + By^2)^{\frac{7}{2}}}$$

is connected with the known equations for motion about the focus in an elliptic orbit in a plane inclined to the plane of reference; for if a sphere described with the focus as centre cut the plane of the orbit and the plane of reference in NP and NM, and if PM be a great circle perpendicular to NM, then $PM = s$, and if u denote the reciprocal of the projection of the radius vector upon the plane of reference, it is well known that

$$lu = \sqrt{(1+s^2)} + e\cos(\theta - \varpi) \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

where l is the semi-latus rectum of the orbit. But if h denote twice the area described in unit of time by the projection of the radius vector,

$$\frac{d^2u}{d\theta^2} + u = \frac{P\cos PM}{h^2u^2}$$

$$= \frac{\mu}{h^2}\cos^3 PM$$

$$= \frac{\mu}{h^2}\frac{1}{(1+s^2)^{\frac{3}{2}}}.$$

Now $s = k \sin(\theta - \gamma)$, so that the differential equation is

$$\frac{d^2u}{d\theta^2} + u = \frac{\mu}{h^2} \frac{1}{\{1 + k^2 \sin^2(\theta - \gamma)\}^{\frac{3}{2}}},$$

while (10) becomes

$$lu = \sqrt{\{1 + k^2 \sin^2(\theta - \gamma)\}} + e \cos(\theta - \varpi);$$

and therefore, transforming from polar to rectangular coordinates, if the law of force is

$$\frac{\mu'}{\{(1 + k^2 \sin^2\gamma)\, x^2 - 2k^2 \sin\gamma \cos\gamma\, xy + (1 + k^2 \cos^2\gamma)\, y^2\}^{\frac{3}{2}}},$$

the equation of the orbit is

$$(1 + k^2 \sin^2\gamma)\, x^2 - 2k^2 \sin\gamma \cos\gamma\, xy + (1 + k^2 \cos^2\gamma)\, y^2 = (Ax + By + l)^2,$$

agreeing with (5). The ordinary equations of elliptic motion thus indicate the laws (1) and (2); and these laws may be found directly by considering the orthogonal projections of a conic on a plane through the focus.

For, the equation of a conic having the origin for focus is

$$x^2 + y^2 = (Ax + By + C)^2;$$

and if this be projected orthogonally upon a plane through the focus, the axis of x being the line of intersection of the two planes, the equation of the projection is of the form

$$x^2 + m^2y^2 = (Ax + Bmy + C)^2;$$

that is, any conic having the tangents from the origin equally inclined to the axes, and as we may turn the axes of coordinates through an arbitrary angle, we thus obtain any conic.

§ 13. Newton's law, $\mu \frac{CG^3}{OP^2}$, for the force to O may be put in the form

$$\mu \frac{DD'^3}{OP^2 . PP'^3} \quad \ldots\ldots\ldots \quad (11)$$

where PP′ is the chord through O and DD′ is the diameter parallel to the chord PP′; for if PM be drawn parallel to the line joining C to the middle point of PP′, cutting CD in M, then $CG.CM = CD^2$, and therefore $2CG.PP = DD'^2$. The form (11) was given in an examination paper set in St. John's College, Cambridge, in December 1869, and I am indebted to Mr. E. J. Routh for the reference to it.

By a known theorem, if a, b be the semi-axis major and semi-axis minor of an ellipse

$$PP' = \frac{1}{2a} DD'^2 \sqrt{\left(1 - \frac{p_1 p_2}{b^2}\right)},$$

p_1, p_2 being the perpendiculars upon the chord PP′ from the foci S, H; and therefore, if the body describe an elliptic orbit about O,

$$\text{force to O} = \frac{\mu}{r^2 (b^2 - p_1 p_2)^{\frac{1}{2}}},$$

where $OP = r$ and p_1, p_2 have the same or opposite signs according as S, H are on the same or on opposite sides of PP′.

If the orbit be hyperbolic

$$\text{force to O} = \frac{\mu}{r^2 (b^2 + p_1 p_2)^{\frac{1}{2}}},$$

b being the semi-conjugate axis.

Consider the case when the orbit is an ellipse. Since

$$\frac{CG^2}{OP^2} = \left(\frac{p_o}{p}\right)^2 r, \text{ by § 2,}$$

and also,

$$= \frac{1}{r^2} \left(\frac{DD'^2}{2PP'}\right)^2 = \frac{1}{r^2} \frac{(ab)^2}{(b^2 - p_1 p_2)^{\frac{1}{2}}},$$

it follows that

$$\frac{p_o}{p} = \frac{1}{r} \frac{ab}{\sqrt{(b^2 - p_1 p_2)}}.$$

Now, when the force $= \frac{\mu r}{p^3}$, the periodic time $= \frac{2\pi}{\sqrt{\mu}} p_o^{\frac{1}{2}}$, and therefore when the force

$$= \mu \frac{a^2 b^2}{p_o^3} \frac{1}{r^2} \frac{1}{(b^2 - p_1 p_2)^{\frac{1}{2}}},$$

the periodic time $= \frac{2\pi}{\sqrt{\mu}} p_o^{\frac{1}{2}}$. Putting $\mu' = \mu \frac{a^2 b^2}{p_o^3}$, the periodic time

$$= \frac{2\pi}{\sqrt{\mu}} p_o^{\frac{1}{2}} = \frac{2\pi}{\sqrt{\mu'}} (ab)^{\frac{1}{2}},$$

and therefore when the force to O

$$= \frac{\mu}{r^2 (b^2 - p_1 p_2)^{\frac{1}{2}}},$$

the periodic time

$$= \frac{2\pi}{\sqrt{\mu}} (ab)^{\frac{1}{2}}.$$

When O coincides with a focus, $p_1p_2 = 0$; the force to $S = \frac{\mu}{b^3} \cdot \frac{1}{r^3} = \frac{\mu'}{r^3}$ suppose, and the periodic time

$$= \frac{2\pi}{\sqrt{\mu}} a^{\frac{3}{2}} b^{\frac{3}{2}} = \frac{2\pi}{\sqrt{\mu'}} a^{\frac{3}{2}}.$$

When O coincides with the centre,

$$p_1p_2 = -a^2e^2 \sin^2 \theta,$$

where θ is the inclination of CP to the major axis, therefore

$$\text{force to O} = \frac{\mu}{r^3 (b^2 + a^2e^2 \sin^2 \theta)^{\frac{3}{2}}}$$

$$= \frac{\mu}{r^3 (a^2 \sin^2 \theta + b^2 \cos^2 \theta)^{\frac{3}{2}}}$$

$$= \frac{\mu}{r^3} \cdot \frac{r^3}{a^3b^3} = \frac{\mu}{a^3b^3} r = \mu' r,$$

and the periodic time

$$= \frac{2\pi}{\sqrt{\mu}} (ab)^{\frac{3}{2}} = \frac{2\pi}{\sqrt{\mu'}}.$$

§ 14. The substance of the above paper was communicated to the Royal Astronomical Society on December 14, 1877, and an abstract appeared in the account of that meeting in the *Observatory*, vol. i., p. 268 (January 1878); but I have been prevented by other occupations from writing out the paper till now. The theorem that if a body moves under the action of a central force $\frac{\mu r}{p^3}$ the periodic time is $\frac{2\pi}{\sqrt{\mu}} p_0^{\frac{3}{2}}$ was set by me in the Mathematical Tripos, Wednesday morning, January 2, 1878 (see *Solutions of the Senate-House Problems and Riders for* 1878, pp. 41–43).

Trinity College, Cambridge,
1878, *August* 29.

On a Portable Star Finder for Altitude and Azimuth Telescopes.

By Edward H. Liveing, A.R.S.M.

The following is a description of an instrument that I invented in the early part of last year, and that I have had in actual use about twelve months.

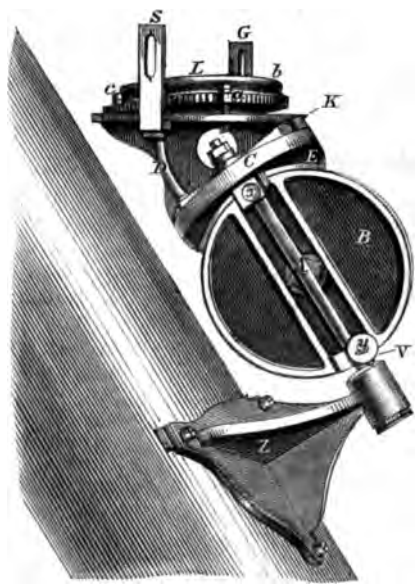
My object in describing it is that I think it may be very useful with the altitude and azimuthly mounted reflectors so much in use among amateurs and others at the present day.

It differs from an ordinary Equatoreal in the facts that it weighs only a few ounces, and that, instead of carrying the telescope, it is itself carried by it, being employed only to direct the telescope, not to support it.

It requires no fixed or adjusted stand. The telescope and stand can be taken in and out of the house at will, and are always ready for use at once.

It enables the time to be ascertained when the Sun or any other celestial object (whose declination and R.A. are known) is visible: this it does by taking an altitude and giving the hour-angle mechanically, without calculation.

I will now, with the aid of the figure, describe its construction.



A is a spindle attached to a telescope by a bracket Z, the spindle being parallel to the optical axis of the telescope;* this spindle carries the circle B, which forms the declination circle of the instrument. This circle is movable around the spindle in the bearings x and y, but its plane remains parallel to the spindle, and therefore to the telescope. Upon the flat surface of this circle moves a brass plate E, carrying at one end a vernier V to read the graduated edge of the declination circle, and at the other the hour circle C of the instrument. Upon the surface of C turns the colatitude bracket D, carrying a vernier K to read the hour circle, and also a circular spirit level L, and two sights,

* See mode of adjustment at end of Paper.

S and G, clamped upon its edge and capable of being secured in any desired position.

Now, before the instrument can be used to find objects, an azimuth mark must be fixed upon, and, for simplicity of description, we will suppose some distant well defined terrestrial object to be visible from the situation where the telescope stands.

Then, to fix the sights, proceed thus:—Set the declination vernier to the declination of the Sun at the time; now direct the telescope to the Sun, so that that object is in the centre of the field; next render the circular spirit level true by moving the hour circle motion, and also the whole instrument about the spindle A. This done, adjust and clamp the sights so as to bisect the distant object fixed upon;* now read the hour circle, which gives the hour angle of the Sun at the moment, which, added to the Sun's R.A. = the sidereal time. To this having set a clock or watch, we are ready to find any object with the instrument in the following manner:—

Set the declination vernier to the declination of the object and the R.A. vernier to its hour angle (that is the sidereal time — the right ascension); now render the level correct by moving the telescope in altitude, and also the instrument on the spindle A; this done, move the telescope in azimuth until the sights bisect the distant object, and if all is done right the star will be in the field.

And conversely, if it be required to determine the R.A. and declination of a body for identification, proceed thus:—turn the telescope on the object, noting the sidereal time; move the instrument so that the level is true and the azimuth object bisected by the sights; read the declination circle, which gives the declination of the object, and the R.A. circle, which gives the hour angle of the object, which — the sidereal time = its R.A.

Now supposing no distant terrestrial object suitable for an azimuth mark to be visible from the situation where the telescope stands, the following method may be employed:—

At any convenient distance and direction fix up horizontally two deal laths, in such a manner that a line joining them passes through the place where the telescope stands. This done, direct the telescope as before described to the Sun, setting the instrument to his declination and moving until level; then fix the sights so that they cut the laths near the middle when looking backwards or forwards through them; now mark the points on

* In fixing azimuth marks in the manner described by aid of the Sun or other celestial object, it is well to choose a time when their altitude is changing pretty rapidly, and not when near the meridian; if, however, the local time is known, this restriction is not necessary, as in that case the R.A. circle may be set to the hour angle of the Sun in addition to setting the declination circle to his declination; indeed, in any case when the time is known, it is well to do this, as it insures increased accuracy in fixing the azimuth marks.

the laths where they cut, and mark off also a rough scale of equal parts on both sides from these central marks. The object of these double azimuth marks is to avoid parallax, and their use is very simple: thus, in the case of finding an object, proceed as before directed so far as regards setting to declination and hour angle and setting the instrument level; then, looking through the sights, move the telescope in azimuth until the central mark on one of the laths is cut; now, looking backwards through the sights, note at how many divisions from the central mark they cut the lath; reduce them to half* the number by moving the telescope in azimuth; the line of sight is now parallel to the line joining the central marks on the laths.

It will be seen that the telescope can be set down anywhere between the laths and is ready for use at once.

In the above account I have avoided going into detail so as not to confuse the description, but it is desirable I should mention a few points I have omitted.

First as to the dimensions of the instrument: one made with 2-inch circles will, I think, be found the most useful size; circles of this size can be made to read to 2″ of arc; it is of great importance that the declination circle be well graduated.

Secondly as regards the sights employed: I have found the simple form of slit and wire sights, such as are used for compasses, to answer very well; they will read either way nearly equally well, that is with the slit next the eye (the ordinary way of using them) or with the wire next the eye; in the latter case, however, the distance between them must not exceed a few inches, as it renders the field of view so inconveniently small when looked through in the reverse direction. With 3 inches distance between the sights they will read to 4′ or even less without difficulty.†

Of course, if greater accuracy is required, it can be obtained by the use of a small telescope, about 4–5 inches long and ⅝ in. aperture, resting in Y bearings, which take the place of the sights.

There are certain positions of the instrument where a small reflector or reflecting prism is required to enable the sights to be seen through.‡

I should mention the whole instrument can be made to lift off the steel spindle, so that when not in use it can be kept in its own case, the necessary friction to the motion upon the spindle being given by the clamp screw *y*.

The circular spirit level is adjusted by the three screws *a*, *b*, *c*, which give a certain amount of adjustment in latitude. It could

* That is if the telescope is about equally distant from both laths; if not, so move the telescope in azimuth that the sights cut the laths at an equal number of divisions on the same side from the central marks.

† With 5 inches distance between the sights I have found 2′ the maximum error in directing.

‡ Except when the instrument is attached to the telescope near the open end; there, however, it upsets the balance unless counterpoised, and the parallax is greater, and therefore longer deal laths are required.

be easily made adjustable to any latitude, if desired, by having a suitable movement between the level and R.A. circle.

It may be well to state that the instrument shown in the illustration, must only be considered a temporary one, made for the purpose of trying how the method worked, and in several points I think its construction might be improved.

Lastly, I must not forget to mention two suggestions made by my friend Mr. C. V. Boys, namely, having two R.A. circles, and driving the colatitude bracket upon the upper circle by watch-work placed in the bracket and regulated to sidereal time; to find an object it would then only be necessary to set the second hour circle to the R.A. of the object, as with an ordinary Equatoreal provided with double hour circles.

The other suggestion was the addition of a small graduated circle to the movement about the steel spindle, by which addition it would be possible, using an ordinary position angle micrometer on the telescope, to obtain position angles of double stars &c.—the readings of the small circle on the spindle being added to or subtracted from those of the micrometer to obtain the true position angle of the double star observed.

The following are the various adjustments of the instrument, though most should be performed by the maker:—

(1) To determine if the plane of the declination circle be parallel to the axis of the spindle A:—

Place a spirit level on the flat surface of the declination circle (having removed the rest of the instrument) parallel to the direction of the spindle, and level by moving the telescope in altitude; turn the circle through 180° about the spindle; now, placing the spirit level on the opposite face,* observe if it still shows level; any deviation = twice the error.

(2) To ascertain if the R.A. circle is at right angles to the declination circle:—

Having removed the colatitude bracket D and placed a level on the face of the hour circle C parallel to the face of the plate E, move the spindle A and the declination motion until the level shows true during a complete revolution of the instrument around the spindle A. On removing the level and placing it at right angles to the plate E, it will exhibit if the planes of the two circles are at right angles or not.

(3) To determine the index error of the declination circle:—

The instrument being in the position just mentioned, read the declination vernier; the amount that this reading differs from 90° = its index error.

(4) To determine and correct the index error of the R.A. vernier:—

* This supposes the two faces have been turned up parallel to each other.

The spindle A being still as in the last adjustment, truly vertical, put on the colatitude bracket D, and move the R.A. and declination motions till the circular level is true, then the R.A. circle should read 0^h; if not, adjust the level by the screws *a* and *b* until it does.

(5) To adjust the level to the angle of colatitude of the place of observation:—

The spindle as before being vertical, the R.A. vernier at 0^h, and the declination vernier set to the colatitude, adjust the level true by the screw *c*.

(6) To set the spindle parallel to the optical axis of the telescope:—

Set up a scale of equal parts vertically at a distance of 200 yards or so from the telescope, and having placed a spirit level on the surface of the declination circle, parallel to the direction of the spindle (as in the 1st adjustment), move the telescope till it shows level; read scale through telescope; now reverse the telescope, level again as before, note reading of scale again; the midway point between these two readings is the level point; to which having set the telescope, adjust the spindle level by the screws that hold it; now support the telescope on temporary supports the same height as its stand, with the line joining its trunnions vertical, and having directed it to the level point on the distant scale, adjust the spindle level in this direction also.

Note upon the Star Bradley 2935. By Prof. T. H. Safford.

(*Communicated by the Astronomer Royal.*)

The star in question, the *preceding* of a double found in Struve's Dorpat Catalogue, has usually been identified with the *following* component; and this because its proper motion for 100 years is approximately equal to the distance between the two stars.

How the case stands can be readily seen by reducing the extant positions of the preceding star to 1855·0. With the approximate position for that date,

$$22^h\,3^m\,11^s{\cdot}2 \quad \text{and} \quad +82^\circ\,10'\,13'',$$

we obtain the following formulæ for reduction (by precession only) from 1855 to $1855+t$:—

$$\text{In R.A.} \qquad -1^s{\cdot}67298\,t - 0^s{\cdot}3972\,\frac{t^2}{200} - 2^s{\cdot}017\left(\frac{t}{100}\right)^3,$$

$$\text{In Decl.} \qquad +17'{\cdot}5053\,t - 0''{\cdot}1274\,\frac{t^2}{200} - 0''{\cdot}511\left(\frac{t}{100}\right)^3,$$

and thus the following positions for the equinox of 1855·0 :—

Authority.		R.A. h m s	Decl. ° ′ ″	C—O s	C—O ″	No. Obs.
Bradley	1755	22 3 17·72	82 10 17·0	+0·06	+1·1	2.3
Groombridge	1807·8	13·96	14·7	+0·44	+0·8	
Struve	1815·2	13·79		+0·14		1
Struve	1823	13·52	14·6	−0·09	+0·1	6
Schwerd	1828	13·2	15·9	−0·09	−1·4	5
Radcliffe	1844·0		13·0		+0·6	6
Armagh	1844·8		16·1		−2·5	1
Radcliffe	1847·8	12·06		−0·22		3
Armagh	1853·9	9·9		+1·55		1
Carrington	1856·6	11·5	14·1	−0·23	−1·1	3
Yarnall	1866·4	10·58	11·3	+0·07	+1·2	4.2
Airy	1867·7	10·69	13·8	−0·12	−1·3	2
Main	1872·8	10·18	11·1	+0·06	+1·1	4.3

The formula for position and proper motion with which comparison is made is

$$\text{R.A.} = 22^{h}\ 3^{m}\ 11^{s}\cdot38 - {}^{s}0\cdot064\,(t-1855),$$
$$\text{Decl.} = 82^{\circ}\ 10'\ 13''\cdot1 - 0''\cdot05\ (t-1855).$$

The systematic corrections, uncertain in this region, have been applied only for Struve 1815, where the observations are arranged purposely for them; it is at once plain that the following star, which is in about 6ˢ·6 greater right ascension and 3″·3 greater declination, cannot be identical with the one observed by Bradley.

In consquence of the error in identification the proper motion is given

	s	″
By the B.A.C.	+0·017	−0·03.
By Mädler	−0·0101	−0·002.

The latter authority rejects Struve's place of 1823—which I give as used in his discussion, not having the *Positiones Mediæ*—as it does not harmonise with his wrong authorities of later date. The true star is Groombridge 3707, the false one 3709. Slight changes will be necessary in the nomenclature and positions of the Seven-year Catalogue of 1864. The star's proper motion in arc is about 0″·14, in a direction not very far from diametrically opposite to that which the solar motion would give it.

Williams College, Williamstown, Mass.,
June 27, 1878.

On the Results of Meridian Observations of the Mars Comparison Stars. By David Gill, Esq.

Before leaving England for Ascension I applied to all the principal Observatories for their co-operation in observing the Stars I was about to employ in the observations of *Mars*. I would now desire most gratefully to acknowledge the hearty response with which my appeal has been met by most of the principal Observatories, and to tender to the Directors of those institutions my warmest thanks for the invaluable assistance they have thus rendered to me.

I have still to receive the results of a long series of observations made in 1877 and in the present year by Professor Lewis Boss at the Dudley Observatory, as well as the results of observations made in 1877 at Sydney and Liverpool. In addition to this there is the heliometric triangulation, the discussion of which cannot be satisfactorily attempted till all the data depending on meridian observations have been combined and discussed. From twelve Observatories the results have been already received, and for my present purposes I have discussed them in the following paper.

Some unexpected discordances have been found in the re-results of meridian observations at the various Observatories. The explanation of these has raised some interesting and important questions in practical astronomy; and it is in the hope of drawing attention to the subject that I present this paper in its present form.

The following Tables give the immediate results of the observations made at the various Observatories; the small figures below each result indicate the number of observations.

Right Ascensions at the various Observatories depend on the following authorities for the places of the clock stars:—

Königsberg	Verzeichnisses I., *Vierteljahrsschrift der Astron. Gesells.*
Melbourne	*Nautical Almanac* stars, with corrections of $-0^s{\cdot}11$ to *α Columbæ* and $-0^s{\cdot}07$ to *Sirius*, besides additional stars selected from the same Greenwich General Catalogue (1860).
Pulkowa	Verz. I., *Viert. Ast. Gesells.*
Leipzig	Do.
Greenwich	The new Nine-Year Catalogue (Greenwich clock stars).
Berlin	*Nautical Almanac* and Greenwich clock stars.
Leiden	Verz. I., *Viert. Ast. Gesells.*
Paris	Clock stars of Paris Observatory.
Washington	American Ephem. and Washington clock stars.
Cambridge, U.S.	Star places on p. 164, vol. ix., *Proceedings, American Academy*, with a correction, $-0^s{\cdot}016$, to reduce to the equinox of the Verz. I., *Viert. Ast. Gesells.*
Cordoba	American Ephem.
Oxford	*Nautical Almanac.*

Meridian Observations of Mars Comparison Stars, 1877.

Right Ascensions.

	Königsberg.			Melbourne.	Pulkowa.	Leipzig.	Greenwich.	Berlin.	Leiden.	Paris.	Washington.	Cambridge, U.S.	Cordoba.	Oxford.
	h	m	s	s	s	s	s	s	s	s	s	s	s	s
a	22	47	0·022	·027	*·980	·089	·020	*·973	·090	·014	—	·056	·162	·037
			5	3	3	4	10	4	12	5		6	5	7
b		47	37·753	·803	·791	·748	·784	·780	·866	·908	·917	·892	·854	·761
			6	3	6	3	5	4	4	5	3	6	5	7
a		51	39·420	·577	·464	·390	·550	·505	·648	·456	·660	·767	·634	·408
			7	3	5	3	5	2	4	5	3	3	5	5
c		53	6·920	·910	·918	·937	·920	·888	·986	·982	—	·980	·951	·954
			6	3	5	2	5	4	7	6		6	7	8
β		56	5·544	·487	·522	·545	·526	·580	·641	·540	·687	·628	·572	·463
			6	3	6	4	5	3	2	5	3	6	5	6
μ		58	2·943	—	·975	·930	·932	·897	*·008	—	*·063	—	·960	·914
			6		5	2	5	3	2		3		4	5
d		59	27·942	·880	·880	·780	·844	·800	·913	·878	·973	·968	·888	·817
			6	3	3	1	5	2	3	6	3	6	5	4
γ	23	0	31·624	·553	·545	·580	·595	·590	—	·577	·720	·677	·620	·530
			5	3	2	2	6	1		3	3	6	5	4
e		0	57·928	·875	·954	·940	·912	·920	·957	·730	·987	*·030	*·012	·810
			4	4	5	2	5	3	4	1	3	6	5	3
δ		5	3·872	·853	·862	·610	*·010	·915	*·021	—	*·070	·993	·974	·890
			5	3	5	2	4	2	3		3	6	5	3

Meridian Observations of Mars Comparison Stars, 1877—continued.

Right Ascensions.

	Königsberg.	Melbourne.	Pulkowa.	Leipzig.	Greenwich.	Berlin.	Leiden.	Paris.	Washington.	Cambridge, U.S.	Cordoba.	Oxford.
	h m s	s	s	s	s	s	s	s	s	s	s	s
**ϵ_0	5 33·468 6	·413 3	·543 3	·700 1	·496 6	·463 3	·586 1	—	·647 3	·658 6	·564 10	[·342]†
θ	7 21·—	—	—	·590 1	·592 5	·515 2	—	—	—	—	—	—
f	8 15·492 5	·418 4	·475 2	·290 1	·395 4	·380 2	—	·329 2	·640 3	·507 6	·498 5	·470 2
g	8 55·935 4	·830 3	·902 6	·755 2	·913 4	·840 5	·949 4	—	*·003 3	·933 6	·890 5	·740 1
$\psi_1 Aq.$	9 26·810 4	·785 4	—	·760 1	·818 5	·715 2	·794 2	·620 1	·890 3	·830 6	·870 5	·808 4
h	11 14·822 5	·740 3	·820 4	·758 2	·728 5	·725 4	·831 2	·760 3	·847 3	·832 5	·752 5	·664 5
i	12 33·740 3	·729 4	·767 3	·705 2	·690 9	·683 3	·759 1	·690 1	·837 3	·769 6	·758 5	·612 5
k	12 37·030 4	·033 3	·063 3	·025 2	·050 4	*·990 3	·089 4	—	·140 3	·170 6	·044 5	*·883 3
l	14 28·600 7	·547 3	·565 4	·503 3	·552 5	·560 5	·658 2	·537 3	·710 3	·642 6	·552 5	·468 4
λ	16 37·534 5	·460 3	·457 3	·340 2	·488 5	·457 3	·575 2	·413 2	·673 3	·555 6	·490 5	·365 4

ζ	16	54·365 (4)	·383 (3)	·350 (4)	·285 (2)	·404 (5)	·327 (3)	·414 (3)	—	·457 (3)	·503 (6)	·430 (5)	·283 (3)
η	20	13·325 (8)	·307 (3)	·320 (3)	·240 (1)	·364 (5)	·290 (3)	·419 (3)	·230 (4)	·490 (2)	·437 (6)	·368 (5)	·207 (7)
m	21	41·066 (7)	·080 (3)	·118 (5)	*·940 (3)	·100 (5)	·037 (3)	·144 (4)	·050 (4)	·200 (3)	·080 (6)	·132 (5)	*·986 (7)
n	22	38·841 (8)	·840 (4)	·883 (3)	·920 (1)	·829 (7)	*790 (4)	·869 (2)	·750 (1)	·953 (4)	·925 (6)	·884 (5)	·771 (8)
q	26	3·370 (7)	·397 (3)	·390 (5)	·308 (2)	·413 (4)	·345 (4)	·451 (7)	·376 (5)	·527 (3)	·458 (6)	·425 (4)	·363 (9)
r	29	5·707 (7)	·657 (3)	·653 (4)	·720 (2)	·676 (5)	*653 (3)	·733 (4)	·623 (3)	·830	·782 (6)	·710 (5)	·674 (7)
s	29	39·281 (7)	·280 (3)	·320 (3)	·320 (1)	·276 (5)	·255 (4)	·314 (2)	·230 (2)	·447 (3)	·328 (6)	·350 (6)	·149 (7)
t	31	51·314 (7)	·300 (3)	·350 (1)	·173 (3)	·282 (6)	·245 (4)	·347 (7)	·233 (6)	·437 (3)	·315 (6)	·304 (5)	·250 (7)

** By ε, is to be understood the mean of the two components of this double star.

† It is not mentioned which component of the double star ε was observed.

Meridian Observations of Mars Comparison Stars, 1877—continued.

Declinations.

	Königsberg.	Melbourne.	Pulkowa.	Leipzig.	Greenwich.	Berlin.	Leiden.	Paris.	Washington.	Cambridge, U.S.	Cordoba.	Oxford.
	° ′ ″	″	″	″	″	″	″	″	″	″	″	″
a	−12 16 11·98 5	11·54 6	12·79 3	12·68 4	11·34 9	12·65 4	11·92 12	11·43 3	—	12·34 6	11·90 5	12·10 9
b	−12 50 33·96 5	33·96 4	34·65 6	34·97 3	33·57 5	35·30 4	34·18 4	34·28 4	34·23 3	34·33 6	33·26 5	34·95 7
a	−11 47 21·63 6	20·94 3	21·09 5	22·30 3	20·55 5	21·30 2	20·43 3	19·67 3	21·47 3	20·40 3	20·50 5	20·80 6
c	−13 43 45·66 5	45·57 7	46·66 5	47·72 2	45·15 5	46·84 5	45·92 7	46·11 7	—	46·35 6	45·26 7	46·51 8
β	−11 55 33·93 6	34·26 4	34·75 6	35·16 4	33·92 5	35·30 3	34·99 2	33·53 4	35·57 3	34·09 6	34·06 5	35·13 5
μ	−12 50 28·26 5	—	28·39 5	29·08 2	28·07 5	28·70 3	28·20 2	—	28·37 3	—	27·22 4	28·65 6
d	−11 6 1·37 4	3·24 3	3·83 3	3·74 1	2·84 5	4·45 2	3·64 3	2·80 3	4·76 3	3·83 5	2·32 5	4·84 4
γ	−13 23 27·14 5	26·96 4	28·50 2	27·61 2	26·57 5	28·40 1	—	27·60 3	27·93 3	27·55 6	26·60 5	27·69 4
e	−12 28 14·70 3	15·34 4	15·39 5	17·15 2	14·88 5	15·93 3	14·68 4	14·00 1	16·67 3	15·48 6	15·18 5	14·98 4

δ	−11	10	31·78 (5)	32·24 (4)	32·75 (5)	31·90 (2)	31·12 (4)	33·00 (2)	31·87 (4)	—	33·96 (3)	31·95 (6)	31·50 (5)	32·59 (4)
ϵ_a	−12	36	0·90 (5)	0·95 (3)	1·82 (3)	0·73 (1)	1·46 (5)	2·50 (3)	1·49 (1)	—	2·02 (3)	1·78 (6)	0·87 (10)	[2·94] (4)
θ	−14	3	—	—	—	47·84 (1)	46·10 (5)	46·70 (2)	—	—	—	—	—	—
f	−11	21	24·70 (5)	25·20 (3)	24·91 (2)	25·84 (1)	24·70 (4)	26·50 (2)	—	26·35 (2)	26·16 (3)	25·29 (6)	25·06 (5)	25·33 (4)
g	−12	14	4·53 (4)	3·76 (3)	4·59 (6)	4·49 (2)	4·63 (4)	5·98 (5)	4·74 (5)	—	6·10 (3)	5·61 (6)	4·70 (5)	5·37 (3)
ψ_1 *Aq.*	− 9	45	26·40 (3)	26·80 (3)	—	27·30 (1)	26·80 (5)	27·10 (2)	27·01 (2)	28·20 (1)	27·07 (3)	27·69 (6)	26·76 (5)	27·44 (4)
h	−12	23	3·12 (4)	3·88 (3)	4·08 (3)	4·89 (2)	3·40 (6)	4·98 (4)	3·93 (2)	4·70 (3)	3·90 (3)	4·44 (5)	3·52 (5)	4·43 (6)
i	−11	16	56·10 (4)	57·60 (3)	59·27 (3)	58·17 (2)	57·28 (9)	58·73 (3)	57·37 (1)	58·70 (1)	59·57 (3)	58·43 (6)	57·32 (5)	58·46 (9)
k	−12	50	34·10 (3)	32·93 (3)	34·29 (3)	33·96 (2)	33·00 (4)	34·30 (3)	33·56 (4)	—	33·33 (3)	33·85 (6)	33·28 (5)	34·21 (3)
l	−11	12	18·70 (5)	19·12 (3)	19·74 (4)	20·46 (3)	19·76 (5)	20·36 (5)	18·96 (2)	19·25 (2)	21·11 (3)	19·65 (6)	18·80 (5)	17·97 (5)
λ	−11	26	49·70 (4)	50·56 (3)	50·93 (3)	51·79 (2)	50·56 (5)	51·93 (3)	50·77 (2)	51·35 (4)	52·40 (3)	50·92 (6)	50·32 (5)	50·87 (6)

Meridian Observations of Mars Comparison Stars, 1877—continued.

Declinations.

	Königsberg.	Melbourne.	Pulkowa.	Leipzig.	Greenwich.	Berlin.	Leiden.	Paris.	Washington.	Cambridge, U.S.	Cordoba.	Oxford.
	° ′ ″	″	″	″	″	″	″	″	″	′	″	″
ζ	−10 3 32·18 4	32·45 3	34·34 4	32·99 2	32·26 5	33·63 3	32·99 4	—	34·12 3	32·76 6	32·92 5	34·03 4
η	−10 42 36·02 5	36·25 3	37·92 3	38·21 1	36·70 5	37·07 3	37·13 3	37·00 3	38·33 3	36·73 6	37·42 5	36·73 7
m	−12 7 32·80 6	32·60 4	32·87 5	32·84 3	32·70 5	34·00 3	32·89 4	33·65 4	34·37 3	33·62 6	32·92 5	33·73 8
n	− 9 56 32·42 5	32·61 4	34·90 3	33·15 1	32·78 6	33·58 4	33·63 2	34·80 1	33·89 4	33·37 6	32·12 5	33·85 9
q	−11 40 38·70 5	38·58 3	39·21 5	40·07 2	38·88 6	39·80 4	39·30 7	39·30 5	39·67 3	39·85 6	38·45 4	39·53 9
r	−11 14 4·06 5	4·59 3	4·97 4	5·42 2	4·51 5	5·77 3	4·83 4	5·30 3	6·12 3	5·33 6	4·28 5	4·80 7
s	− 9 26 40·66 5	41·00 3	42·34 3	42·03 1	41·60 5	43·23 4	42·32 2	42·15 2	42·25 3	41·77 6	41·76 5	42·34 7
t	− 9 18 27·24 5	27·94 3	29·09 1	28·12 3	27·78 5	28·78 4	27·97 7	28·32 6	29·71 3	28·50 6	27·54 5	28·70 7

I have not stated the authorities for the declinations, as I have not received definite information on all points. I shall merely discuss the declinations to settle the differences of declination, and leave the question of absolute declination for after discussion.

It is necessary, however, to mention here that I have received a letter from Dr. Gould, in which he says: "My latitude determination from five years' observations of circumpolars has lately been brought to completion, and results in a correction of $0''.4$ numerically additive to the declinations communicated; if not too late I will ask you to increase all my declinations by that amount." Dr. Gould's declinations are, however, printed as originally received, but the correction will be taken into account in the final discussion.

The first step was the discussion of the old observations for proper motion. All the existing observations of the stars to be found in Bradley, Piazzi, Lalande, and Bessel were reduced to 1877·0, and in all doubtful cases every existing observation in Argelander, Struve, Airy (Cambridge), Taylor, Pond, the old Greenwich Catalogues, in the Washington Catalogue, and in the Catalogues of Santini was reduced also to 1877·0. I am indebted to Mr. Sadler for searching the Paris observations for recent observations of Lalande's stars.*

Lalande's observations were all reduced from the original *Histoire Céleste* of Lalande, by aid of Von Asten's Tables.

The following systematic corrections to the various Catalogues, founded chiefly on the authority of Auwers in the declinations, and of Newcomb in the right ascensions, were employed :—

	R.A. s	Decl. ″
Bradley	±0·00	±0·00
Piazzi	+0·14	−2·30
Lalande	+0·14	−2·30
Bessel, 1825	+0·02	+0·90
Argelander, 1830	+0·02	−0·61
Cambridge (Airy)	−0·04	−0·54
Pond, 1830	−0·05	−1·51
Taylor, 1835	−0·03	−0·37
Green. Cat. 1840	+0·09	+0·69

Only two of the stars were found to have a proper motion whose effect it would be important to take into account, and of these one (that of ψ_1 *Aquarii*) was found to agree with the proper motion of the Greenwich Catalogue. The other proper

* In the Paris observations the apparent places of these stars only are published, and to find a star it is necessary to search the records for many years. When a star has been found there still remains the reduction to mean place. Let us hope that ere long these useful observations will be printed in a more accessible form. I understand from Admiral Mouchez that this work is to be undertaken at once.

motion is that of the star λ, and it is rather remarkable for so faint a star (8th magnitude); it is shown by the following Table:—

	Epoch.	R.A. 1877·0. h m s	Obs.	Decl. 1877·0. ° ′ ″	Obs.
Piazzi	1800	23 16 35·69	4	−11 27 9·09	4
Lalande	1800	35·21	1 only 1 wire	6·49	1
Bessel	1825	36·21	2	5·38	2
Taylor	1835	36·52	3	0·76	3
Washington	1860	36·92	4	26 56·99	3
Santini	1860	36·97	2	58·99	2
Observation in	1877	37·50	44	50·97	46

The following Table gives the actual results for all the stars:—

Proper Motions and Magnitudes of the Mars Comparison Stars.

	Annual Proper Motion In R.A. s	In Decl. ″	Mag.		Annual Proper Motion In R.A. s	In Decl. ″	Mag.
a	±0·000	0·00	6·0	ψ_1 *Aq.*	+0·024	−0·02	4·5
b	·000	+0·06	6·7*	*h*	·000	0·00	6·2
a	− ·002	−0·03	9·5	*i*	·000	0·00	5·2
c	− ·001	0·00	6·0	*k*	− ·005	0·00	7·5
β	− ·008	−0·01	7·7	*l*	·000	−0·02	7·5
μ	·000	−0·04	[8·0]	λ	+0·023	+0·26	8·0
d	·000	−0·03	7·5	*ζ*	·000	0·00	8·0
γ	·000	−0·05	8·5	*η*	− ·004	0·00	8·7
e	− ·004	0·00	7·5	*m*	·000	0·00	6·8
δ	− ·005	−0·05	9·0	*n*	− ·008	0·00	6·5
ϵ_0	− ·004	0·00	8·1	*q*	·000	0·00	7·0
θ	·000	0·00	[7·0]	*r*	·000	0·00	7·0†
f	·000	0·00	7·0	*s*	− ·006	0·00	7·5
g	− ·001$_5$	−0·03	7·0	*t*	·000	−0·04	6·5

The mean epoch of the preceding observations is 1877·80. All the observations were made in August, September, October, November, and December of that year, and it is seldom that the mean epoch of the observations of any star at any Observatory

* Bessel, Lalande, and Santini give respectively 7–8, 8, and 7–8 for the magnitude of this star. At Melbourne it is noted Oct. 24 mag. (7) and Oct. 31 (6½); my own recollection confirms these latter estimates.

† Bessel and Santini both estimate this star 8 mag., and it is so in the Berlin Star Maps. It was observed as 7 mag. both Oct. 4 and Oct. 31 at Melbourne.

The magnitudes of *μ* and *θ* are not derived from modern observations; all the other magnitudes are from the excellent magnitude estimations of the Melbourne observations of the *Mars* stars.

differs $\frac{1}{10}$ year from this epoch, and none differ so much as $\frac{3}{10}$ of a year. Hence for the largest proper motion (that of ψ_1 *Aquarii* or λ) the extreme error of assuming the epoch 1877·80 for all observations can never amount to $\frac{1}{10}''$ of arc, and is an insensible quantity in the mean. We may therefore proceed to find the systematic corrections required to reduce each series to a common system of right ascensions and declinations without regarding the proper motions for the present.

Several courses are open; but that which, for reasons afterwards explained, appears to be the best is to assume that the best value of the absolute right ascension and declination will be found from the mean of the results from all the different Observatories, care being taken to ascertain that at each Observatory everything has been done, as far as possible, to eliminate systematic error and secure an absolute result.

It may of course be urged that at a good many Observatories the same system of standard stars was employed, that therefore all the right ascensions are affected by the common systematic error due to that system of right ascension, and that at other Observatories the declinations have no pretensions to be absolute, but are merely derived from differences of declination from the fundamental stars. Practically, however, these arguments are not exact; for even when the same system of fundamental stars and star places has been employed at two Observatories, there are still systematic discordances in the resulting right ascension of the *Mars* stars amounting to $0^s{\cdot}07$ of time, and when different fundamental stars are employed, there are systematic discordances nearly three times greater than can be accounted for by systematic difference in the system of the fundamental stars employed.

It would appear then that there are sources of systematic error peculiar to each Observatory; and it being impossible to say *à priori* which Observatory is least liable to such systematic errors, the proper course with our present data is to adopt the mean system as probably the most accurate.

To find an absolute mean system it is necessary that all the stars should be observed an equal number of times at all the Observatories, and that the observations at each Observatory should be equally good. The mean of the right ascensions and declinations of each star would then be the most probable value of these coordinates.

None of these conditions are completely fulfilled in the case before us. There are, however, 16 stars which have been observed at all the Observatories; so that if we subtract the right ascension and declination of each Observatory's result from the mean result of each of these 16 stars, we shall have 16 values of the systematic corrections, the mean of which will be a close approximation to the true mean corrections. The results of this process for the right ascensions are given in the following Table, and I shall deal with these in the first place.

Corrections of the Right Ascensions to mean for

	Mean.	Königsberg.	Melbourne.	Pulkowa.	Leipzig.	Greenwich.	Berlin.	Leiden.	Paris.	Washington.	Cambridge.	Cordoba.	Oxford.
	s	s	s	s	s	s	s	s	s	s	s	s	s
b	37·821	+·068	+·018	+·030	+·073	+·037	+·041	−·045	−·087	−·096	−·071	−·033	+·060
a	39·540	+·120	−·037	+·076	+·150	−·010	+·035	−·108	+·084	−·120	−·227	−·094	+·132
β	5·561	+·017	+·074	+·039	+·016	+·035	−·019	−·080	+·021	−·126	−·067	−·011	+·098
d	27·880	−·062	·000	·000	+·100	+·036	+·080	−·033	+·002	−·093	−·088	−·008	+·063
e	57·921	−·007	+·046	−·033	−·019	+·009	+·001	−·036	+·191	−·066	−·109	−·091	+·111
h	14·773	−·049	+·033	−·047	+·015	+·045	+·048	−·058	+·013	−·074	−·059	+·021	+·109
i	33·728	−·012	−·001	−·039	+·023	+·038	+·045	−·031	+·036	−·109	−·041	−·030	+·116
l	28·575	−·025	+·028	+·010	+·072	+·023	+·015	−·083	+·038	−·135	−·067	+·023	+·107
λ	37·484	−·050	+·024	+·027	+·144	−·004	+·027	−·091	+·071	−·189	−·071	−·006	+·119
η	13·333	+·008	+·026	+·013	+·093	−·031	+·043	−·086	+·103	−·157	−·104	−·035	+·126
m	41·078	+·012	−·002	−·040	+·138	−·022	+·041	−·066	+·028	−·122	−·002	−·054	+·092
n	38·855	+·014	+·015	−·028	−·065	+·026	+·065	−·014	+·105	−·098	−·070	−·029	+·084
q	3·402	+·032	+·005	+·012	+·094	−·011	+·057	−·049	+·026	−·125	−·056	−·023	+·039
r	5·702	−·005	+·045	+·049	−·018	+·026	+·049	−·031	+·079	−·128	−·080	−·008	+·028
s	39·296	+·015	+·016	−·024	−·024	+·020	+·041	−·018	+·066	−·151	−·032	−·054	+·147
t	51·296	−·018	−·004	−·054	+·123	+·014	+·051	−·051	+·063	−·141	−·019	−·008	+·046
Mean		+·004	+·018	−·001	+·057	+·014	+·039	−·055	+·053	−·121	−·073	−·027	+·092

These mean corrections must necessarily be very close approximations to the true systematic corrections, and they may therefore be safely employed to correct the positions of the stars in which observations have been secured at only nine, ten, or eleven Observatories.

Thus the star *a* was not observed at Washington; the correction to the mean result of the eleven remaining Observatories will of course be the mean of the corrections for these Observatories. But the sum of all the corrections is 0; therefore the sum of the corrections for the star *a* will be

$$0 - (\text{Washington correction}),$$

and its mean

$$-\frac{\text{Washington correction}}{11} = -\frac{0^{s}\cdot 121}{11} = 0^{s}\cdot 011.$$

The following Table gives the uncorrected means of the incomplete series, with their corrections, and the corrected results so found.

	Places where Observations are wanting.	Uncorrected Mean Sec. of R.A.	Correction.	Resulting Mean Sec. of R.A.
		s	s	s
a	Washington	60·043	+ 0·011	60·054
c	Washington	6·941	+ ·011	6·952
μ	Melbourne, Paris, and Cambridge	2·958	± ·000	2·958
γ	Leiden	31·601	+ ·005	31·606
δ	Paris	3·915	− ·005	3·910
ε	Paris and Oxford	33·554	− ·007	33·547
f	Leiden	15·445	+ ·005	15·450
g	Paris	55·881	− ·005	55·876
ψ_1 *Aq.*	Pulkowa	26·791	± ·000	26·791
k	Paris	37·047	− ·005	37·042
ζ	Paris	54·382	− ·005	54·377

Subtracting the result of each Observatory from the mean right ascension so found, we get the following corrections:—

	Königsberg.	Melbourne.	Pulkowa.	Leipzig.	Greenwich.	Berlin.	Leiden.	Paris.	Washington.	Cambridge, U.S.	Cordoba.	Oxford.
a	+ ·032	+ ·027	+ ·063	− ·035	+ ·034	+ ·081	− ·047	+ ·040	—	− ·002	− ·108	+ ·017
c	+ ·032	+ ·042	+ ·034	+ ·015	+ ·032	+ ·064	− ·034	− ·030	—	− ·028	+ ·001	− ·002
μ	+ ·015	—	− ·017	+ ·028	+ ·026	+ ·061	− ·050	—	− ·105	—	− ·002	+ ·044
γ	− ·018	+ ·053	+ ·061	+ ·026	+ ·011	+ ·016	—	+ ·029	− ·114	− ·071	− ·014	+ ·076
δ	+ ·038	+ ·057	+ ·048	+ ·300	− ·100	− ·005	− ·111	—	− ·160	− ·083	− ·064	+ ·020
ϵ	+ ·079	+ ·134	+ ·004	− ·153	+ ·051	+ ·084	− ·039	—	− ·100	− ·111	− ·017	—
f	− ·042	+ ·032	− ·025	+ ·160	+ ·055	+ ·070	—	+ ·121	− ·190	− ·057	− ·048	− ·020
g	− ·059	+ ·046	− ·026	+ ·121	− ·037	+ ·036	− ·073	—	− ·127	− ·057	− ·014	+ ·136
ψ_1	− ·019	+ ·006	—	+ ·031	− ·027	+ ·076	− ·003	+ ·171	− ·099	− ·039	− ·079	− ·017
k	+ ·012	+ ·009	− ·021	+ ·017	− ·008	+ ·052	− ·047	—	− ·098	− ·128	− ·002	+ ·159
ζ	+ ·012	− ·006	+ ·027	− ·092	− ·027	+ ·050	− ·037	—	− ·080	− ·126	− ·053	+ ·094
Mean	+ ·007	+ ·040	+ ·015	+ ·037	+ ·001	+ ·053	− ·049	+ ·065	− ·119	− ·070	− ·036	+ ·051

Combining the results of both tables, having regard to the number of observations in each, we get the following corrections to a mean system derived from all the stars observed:—

Systematic Correction to Mean System of Right Ascensions.

	s		s
For Königsberg	+·005	For Leiden	−·053
„ Melbourne	+·026	„ Paris	+·055
„ Pulkowa	+·005	„ Washington	−·120
„ Leipzig	+·049	„ Cambridge, U.S.	−·072
„ Greenwich	+·009	„ Cordoba	−·032
„ Berlin	+·044	„ Oxford	+·076

I devoted a good deal of time and thought to an endeavour to trace the origin of these systematic discordances, and arrived at the conclusion that they might have three sources:—

1. Difference in the places of the clock stars employed.

2. Errors of pivots producing a change of azimuth, buckling of the cube, or unsymmetrical flexure of the axis in the various transit instruments when directed to different altitudes, producing a change of collimation; the clock stars employed having, as a rule, much greater north declination than the stars observed, a systematic error would be thus created.

3. An error like a personal equation depending on the magnitude of the star.

The reasons which led me to believe that this last was a probable source of error were as follows:—

There appear to be two distinct habits of observing transits with the chronograph, and from conversation with a good many observers, I think the following is the one generally adopted: viz. to endeavour to tap the key at the instant the star is bisected by the transit web; in other words, to give the mental message, to tap just so much in advance that the sound of the tap shall coincide with the instant of bisection of the disk to the eye. Observers unconsciously train themselves to this habit; but Dr. Gould, in his *Transatlantic Longitude*, has shown that it is liable to serious objection. He points out that this method of observing gives rise to a personal equation varying with the declination, the observer of course tapping too soon for slow moving and too late for quick moving stars. For this reason Dr. Gould urges the necessity of the observer waiting until the star appears actually to be bisected, and *then* giving the mental message to the hand to press the chronograph key. In this mode of observing the actual beat of the key of course comes after the star has been bisected, but the interval will always be a constant one so long as the conditions of the observer's nervous system remains unchanged, and the observer's personal equation will

be the same for stars of all declinations. So with stars of different magnitude. If the observer really waits until the star is bisected by the wire, and *then* gives the mental message to press the key, his results will probably be unaffected by magnitude; but if he is in the habit of giving the pressure a short time before actual bisection, he will be nearly certain to press too soon for very bright and too late for very faint stars, because the larger disk and the rings of a bright star will make it appear closer to the web than the small sharp disk of a faint star at the same angular distance from the web.

This appears to be an easy physical explanation of such a personality.

The complete solution of these points I soon found would require special observations for its satisfactory discussion. I accordingly issued a circular to the Observatories that had taken part in the work, to draw attention to this point. I am happy to say the matter has been warmly taken up at several Observatories, and I hope soon to accumulate much useful information on the subject.

I need only at present communicate the following, to show that there does exist a necessity for the study of personal equation depending on star magnitude.

At Leiden Professor Bakhuyzen has made special observations for the purpose. He observed a star alternately with the full aperture of the instrument (16 centimetres), and with the aperture reduced to 6 centimetres, taking precautions to eliminate effects of possible change of collimation which might be produced by applying the diaphragm.

Observer.	R.A. (Aperture 16 c.) − R.A. Aperture 6 c.).		
E. Tr. d. A. S. Bakhuyzen	−0·070	16 stars	5 7 mag.
Wiltendink	−0·025	8	
Stieltz	−0 051	8	

He found that the application of the diaphragm did not produce any sensible change on the collimation.

Assuming that the mean of all the observations at all the Observatories in the *Mars* star series would be free from systematic error depending on magnitude, he obtained the curves which I have given in the accompanying diagram.

Professor Bakhuyzen has made some very interesting researches founded on the results of the observations which I forwarded to him: but as he is about to communicate them to the *Astronomische Nachrichten*, I need not repeat them here. They go to show that for Observatories using the same clock stars there are systematic differences in the right ascensions of the *Mars* stars amounting to $0^s{\cdot}06$ and $0^s{\cdot}07$, and that the extreme difference of the systems of clock stars is $\pm\ 0^s{\cdot}03$.

The importance of the question will be realised when I state that, as the matter stands, a theoretical astronomer receiving

observations of a minor planet from Washington and Oxford would find an inexplicable difference in the right ascension amounting to three seconds of arc.

A good practical instance came under my own experience in the reduction of the *Juno* observations. I could not reconcile the Greenwich meridian observations of right ascension of *Juno* with the Washington and Cambridge, U.S., results; when the latter were fairly represented, the residuals in the Greenwich observations had all the + sign.* The corrections found in the present investigation reduce the whole to order.

The observations I have requested, together with the heliometric triangulation (which is free from the error in question), will go far to settle the question. Meanwhile, I have thought it best to defer the determination of the absolute right ascension to the end, and discuss the observations now on the supposition that each star is affected by a small systematic error besides the accidental errors of observation.

That is to say, if at any Observatory a star is observed n times, the *mean error* (ϵ) of *one* observation will be found by the well-known formula

$$\epsilon^2 = \frac{[vv]}{n-1}. \quad \ldots\ldots\ldots \quad (1)$$

where $[vv]$ is the usual designation of the sum of the squares of the differences from mean, and the mean error of the result of n observations (ϵ_o) will be found by

$$\epsilon_o^2 = \frac{\epsilon^2}{n}. \quad \ldots\ldots\ldots \quad (2)$$

But if the observations at any Observatory are affected by an error which is systematic for each star, as, for example, if the observer's *personal equation* is different for different star magnitudes, then all the observations of each star will be affected by a systematic error due to this habit of observing, an error which will not be eliminated by any number of observations.

If we denote this systematic *mean error* by s, then the true *mean error* (ϵ_1) of each result will be expressed in the formula

$$\epsilon_1^2 = \epsilon_o^2 + s^2 = \frac{\epsilon^2}{n} + s^2. \quad \ldots\ldots\ldots \quad (3)$$

Our problem then is to find the values of ϵ^2 and s^2 for each Observatory in order to compute the true weights of the various results, and so obtain the definitive right ascension of each star.

The first step is to find the mean error of one observation at each Observatory on the supposition of no systematic error. Each star observed more than once at any Observatory gives

* *Dun Echt Observatory Publications*, vol. ii., p. 204.

a value of the square of the *mean error* (ϵ^2) by formula (1); the mean of all the values of ϵ^2 so found from all the stars, having regard to the number of observations, is the true value of ϵ^2 for each Observatory. The resulting values of ϵ^2 are contained in the accompanying Table:—

	ϵ^2	ϵ
		s
Königsberg	·003110	± ·056
Melbourne	·001790	± ·042
Pulkowa	·005982	± ·077
Leipzig	·012884	± ·113
Greenwich	·006840	± ·083
Berlin	·001391	± ·037
Leiden	·001290	± ·036
Paris	·009644	± ·098
Washington	·004887	± ·070
Cambridge, U.S.	·004457	± ·067
Cordoba	·001046	± ·032
Oxford	·008374	± ·091

Let us now represent by E the true *mean error* of the places which result from the combined observations of all the 12 Observatories. Also for convenience put

α_a, α_b, α_c for the right ascensions of the stars *a*, *b*, *c*, &c., which result from the observations of any particular Observatory; and

α_{oa}, α_{ob}, α_{oc} the right ascensions of the stars *a*, *b*, *c*, &c., derived from the combined results of all the Observatories.

Also put

$$v_a^2 = (\alpha_{oa} - \alpha_a)^2,$$

$$v_b^2 = (\alpha_{ob} - \alpha_b)^2,$$

$$v_c^2 = (\alpha_{oc} - \alpha_c)^2,$$

and v_o^2 = the mean of $(v_a^2 + v_b^2 + v_c^2 + \&c.)$;

that is to say, if there are *m* stars, adopting the usual notation of the method of least squares,

$$v_o^2 = \frac{[v_o v_o]}{m}.$$

Now if α_{oa}, α_{ob}, &c. were true right ascensions of the stars *a*, *b*, &c., then v_o^2 would be the true value of ϵ_1^2 for the particular Observatory under discussion. But as α_{oa}, α_{ob}, &c. are derived from a series of erroneous values of α_a, α_b, &c., made at different Observatories (of which the particular values in question form part), v_o^2 must be smaller than ϵ_1^2, and the true values of ϵ_1^2 become $(v_a^2 + E^2)$, $(v_b^2 + E^2)$, &c. Hence, putting n_v for the mean

number of observations of each star at a particular Observatory, we get the following general equation for the mean error of *one* observation at that Observatory:

$$\epsilon_1^2 = \frac{\epsilon^2}{n_o} + s^2 = v_o^2 + E^2;$$

and if m stars have been observed,

$$s^2 = \frac{[v_o v_o]}{m} + E^2 - \frac{\epsilon^2}{n_o} \quad \ldots\ldots\ldots \quad (4)$$

This equation is of course only correct for a very large value of m; but as for each Observatory m is = from 21 to 27, we may hope to obtain a good determination of the value of s, provided only that the value of E can be independently determined. From the data of the meridian observations alone the problem is indeterminate, unless we assume that the mean of all the Observatories is affected by no systematic error, or rather that the mean of the systematic errors of the 12 Observatories is the same for all the stars. If this is not the case it is still possible to find afterwards the systematic errors of the mean by comparing the places finally derived from the discussion of the meridian observations with the result of the heliometric triangulation, and this is the course I shall adopt.

Of the 27 stars discussed, there were made in all 1278 observations, or an average of 47·7 observations of each star. The mean of the 12 values of ϵ^2 from the 12 Observatories is ·005135, whence

$$E^2 = \frac{\cdot 005135}{47\cdot 7} = \cdot 000108.$$

Computing the values of $\frac{[v_o v_o]}{m} + E^2$, and of $\frac{\epsilon^2}{n_o}$, we get the following Table:—

Square of Mean Error.

	Observed.	Computed.	O−C = s^2
Königsberg	·001824	·000545	·001279
Melbourne	·001134	·000561	·000573
Pulkowa	·001478	·001540	−·000062
Leipzig	·007676	·006212	·001464
Greenwich	·001268	·001300	−·000032
Berlin	·000766	·000437	·000329
Leiden	·000848	·000354	·000494
Paris	·003870	·002737	·001133
Washington	·001091	·001629	−·000538
Cambridge	·002168	·000762	·001406
Cordoba	·001239	·000200	·001039
Oxford	·002525	·001612	·000913

Thus some of the values of s^2 come out with negative signs, and at first it is difficult to see why such an apparent anomaly should be.

Of course, where there is considerable accidental error, but no tendency to systematic error (i.e. if the true value of s is zero), the fact of s^2 coming out a small quantity with a negative sign is merely the result of accident, because our values of v^2, E^2, and ϵ^2 have been deduced from a limited number of equations, and not from an infinite number as supposed by theory.

But, on the other hand, when s^2 comes out with a considerable negative value—for example, in the case of Washington, when in 22 cases out of 27 the computed error exceeds the difference from mean, there can be no doubt that, for some reason, the computed value of ϵ^2 was too great.

A little consideration shows that, after all, this should be so, and that in all really good operations the tendency should be to bring out s^2 with a negative sign. In every investigation observations should be so arranged that, as far as possible, all the systematic errors shall alternately affect the final results with reversed signs. The systematic errors should also be determined by independent means and their effects be applied to the results, and from the agreement of these results *inter se* the value of ϵ be calculated. But if a small error has been made in the determination of any of the constants, the apparent value of ϵ will be increased, whilst s, being included with opposite signs, has a tendency to disappear in the result.

Take an example. Suppose the collimation of a transit instrument has been reduced, as the observer supposes, to zero, but that as a matter of fact, from yielding of the cube or some other cause, a sensible error still remains. A long series of observations made without reversing may yield very consistent results with a small value of ϵ, but all affected by a common error s due to constant collimation error. If the observer reverses the transit several times during the observations, the apparent probable error will be increased, because the constant collimation error will enter in among the accidental errors, though in the mean it would be eliminated. In such a case, if the observations were affected by no other systematic error, ϵ would come out too large, and s^2 would have the negative sign.

This example, however, cannot apply to our case in point, because at Washington the transit instrument was not reversed, and if any error were due to imperfect collimation correction, it would be practically very small, and affect equally all the stars of the zone; it would therefore be included in the systematic correction already applied to all the star places.

But to take a case which is applicable. If different observers are employed at the same Observatory, some of whom have a tendency to observe bright stars too soon relative to faint stars, and others who have the opposite fault, the result would be that the employment of these different observers, whilst it would in-

crease the apparent amount of ϵ, would tend to eliminate s. Hence ϵ being estimated too high, s^2 would come out with the negative sign. To treat the problem rigidly, each observer's results should be dealt with separately, but as the distribution of the observers does not permit this, I am obliged to adopt a less rigid method.

I simply assume that when s^2 has the negative sign its true value is 0, and therefore ϵ^2 has been over-estimated by

$$n_o s^2.$$

Hence, since for Washington $n_o = 3$, we shall have

$$\epsilon^2 = \cdot 004887 - \cdot 001614 = \cdot 003273.$$

Similarly at Greenwich and Pulkowa, where s^2 also comes out negative, the values of ϵ^2 become

	ϵ^2
Greenwich	·00668
Pulkowa	·005734.

the values of n_o being 5 and 4 respectively, the values of s^2 becoming 0 for the three Observatories.

Adopting as the unit of *weight* a *mean error* of $\pm$ 0″·5 of arc on the great circle, that is, of

$$\frac{\pm 0''\cdot 5}{15} \text{ secant } 12^\circ = \pm 0\cdot 0341 \text{ of R.A.}$$

Hence if

$$\text{Weight} = \frac{a}{\epsilon^2},$$

$$a = 0\cdot 001161;$$

and the

$$\text{Weight of any result} = \frac{0\cdot 001161}{\frac{\epsilon^2}{n} + s^2}.$$

where the values of ϵ^2 and s^2 may be taken from the preceding Tables for the required Observatory.

In this way the following Table has been computed :—

Right Ascensions.

			Weights for Number of Observations.										
	ϵ^2	x^2	1	2	3	4	5	6	7	8	9	10	11	12
Königsberg	·003110	·001279	--	--	·56	·64	·70	·75	·79	·82				
Melbourne	·001790	·000573	--	--	1·23	1·46	—	--	—	--				
Pulkowa	·005734	·000000	·21	·60	·81	1·25	1·84	2·69	--	—				
Leipzig	·012884	·001464	·09	·18	·27	·36	—	—	—	—				
Greenwich	·006680	·000000	—	--	·60	·84	1·12	1·44	1·80	2·23	2·72	3·31		
Berlin	·001391	·000329	·80	1·54	2·23	2·86	3·46	--	—	--				
Leiden	·001290	·000494	·86	1·43	1·94	2·37	—	--	3·29	—				4·19
Paris	·009644	·001133	·13	·23	·41	·57	·74	·93	--	--				
Washington	·003273	·000000	--	·69	1·35	2·57	—	--	—	--				
Cambridge, U.S.	·004457	·001406	—	—	·44	—	·56	·61	--	--				
Cordoba	·001046	·001039	—	—	—	1·03	1·08	1·12	1·15			1·21		
Oxford	·008374	·000913	·13	·26	·38	·50	·61	·71	·81	·90	·99			

By a perfectly similar process the Table for the declinations was computed.

The systematic corrections required by the varions Observatories to reduce to the mean declination were found to be—

	"		"		"
Königsberg	−0·71	Greenwich	−0·56	Washington	+0·78
Melbourne	−0·49	Berlin	+0·67	Cambridge	+0·09
Pulkowa	+0·36	Leiden	−0·19	Cordoba	−0·60*
Leipzig	+0·40	Paris	+0·01	Oxford	+0·21

* If Dr. Gould's correction to his latitude determination previously referred to had been applied, this correction would become −0″·20.

The *mean errors* of one observation for each Observatory, derived from the agreement of the observations *inter se*, are given in the following Table, together with the value of s^2 deduced as in the right ascensions.

In the declinations the systematic error s probably depends chiefly, if not entirely, on accidental division error (the periodic division error is practically eliminated by the systematic correction applied to all the declinations of each particular Observatory).

Declinations.

			Weights for Number of Observations.											
	ϵ^2	s^2	1	2	3	4	5	6	7	8	9	10	11	12
Königsberg	1·6710	·0000*	—	—	·45	·60	·75	·90	1·05	1·20				
Melbourne	0·5682	·0000*	—	—	1·32	1·76	—	2·64	3·07	—	—			
Pulkowa	0·6980	·0786	·32	·58	·80	·99	1·15	1·28	—	—	—			
Leipzig	0·6766	·0673	·34	·62	·86	1·06	—	—	—	—	—			
Greenwich	1·0071	·0000	—	—	—	1·48	1·73	1·98	2·23	2·48	2·73			
Berlin	0·2164	·0565	·92	1·51	1·93	2·25	2·51	—	—	—	—			
Leiden	0·2322	·0319	·95	1·69	2·29	2·78	3·19	—	3·84	—	—			4·87
Paris	0·4862	·3585	·30	·41	·48	·52	·54	·56	·58	—	—			
Washington	1·1950	·0464	—	·38	·55	·70	—	—	—	—	—			
Cambridge, U.S.	0·4925	·0217	—	—	1·34	1·72	2·07	2·41	—	—	—			
Cordoba	0·4728	·0503	—	—	—	1·48	1·72	1·94	2·12	—	—	2·56		
Oxford	1·5774	·0037	—	—	·47	·63	·78	·94	1·09	1·24	1·40	1·55		

The values of s^2 marked * come out with a small negative sign, which I have assumed to be the result of accident.

Employing the weights found in the manner described, we obtain the following mean places for the equinox 1877·0 and the epoch 1877·8.

Mean Right Ascensions and Declinations of the Mars Comparison Stars.

For Equinox 1877·0 and Epoch 1877·8.

	R.A. 1877·0.		Weight.	Dcl. 1877·0.			Weight.
a	22 47	0·043	10·24	−12	16	12·12	21·11
b	47	37·815	10·53	−12	50	34·33	17·70
α	51	39·549	9·53	−11	47	20·94	14·79
c	53	6·940	9·63	−13	43	46·14	20·02
β	56	5·561	9·87	−11	55	34·57	16·33
μ	58	2·951	7·87	−12	50	28·27	10·84
d	59	27·876	8·92	−11	6	3·53	14·04
γ	23 0	31·601	7·05	−13	23	27·43	12·15
e	0	57·927	9·58	−12	28	15·37	16·03
ν	5	3·929	8·69	−11	10	32·18	15·36
*ϵ_1	5	33·514	8·04	−12	36	1·66	13·97
n	7	21·580	2·08	−14	3	46·44	3·58
f	8	15·458	7·01	−11	21	25·45	11·70
g	8	55·886	9·60	−12	14	5·03	16·15
ψ_1	9	26·792	7·84	− 9	45	27·21	12·65
h	11	14·766	9·38	−12	23	4·15	15·02
i	12	33·723	9·16	−10	16	58·06	15·33
k	12	37·039	8·83	−12	50	33·70	14·53
l	14	28·579	9·65	−11	12	19·55	15·72
λ	16	37·496	8·88	−11	26	50·97	14·83
ζ	16	54·378	8·95	−10	3	33·09	15·28
η	20	13·340	9·02	−10	42	37·06	15·41
o	21	41·086	10·05	12	7	33·25	17·55
u	22	38·844	10·07	− 9	56	33·31	16·10
q	26	3·402	10·46	−11	40	39·34	18·29
r	20	5·695	9·72	−11	14	5·01	16·37
s	20	30·203	9·27	− 9	26	42·06	15·06
t	31	51·207	10·05	− 9	18	28·25	17·40

Professor Bakhuyzen has also discussed the right ascensions of these stars independently in a most complete and thorough manner; and if I had no farther material on which to base my final results, I should feel disposed to adopt the results of Professor Bakhuyzen without change. As it is, my own results are

* Mean of the two components Σ 2988.

only to be regarded as the first step of a discussion in which the heliometric triangulation and the special observations now being made will form part.

It is very interesting, however, to compare the results arrived at by totally independent methods. Professor Bakhuyzen's right ascensions are reduced to the system of the *Viert. Astron. Gesells.* and require the correction $-0^{s}\cdot020$ to reduce them on the mean to my results. After applying this correction we obtain the following comparison of right ascension :—

	Bakhuyzen—Gill. s		Bakhuyzen—Gill. s		Bakhuyzen—Gill. s		Bakhuyzen—Gill. s
a	+0·007	γ	−0·004	*h*	+0·002	*m*	+0·002
b	− 4	*e*	− 3	*i*	+ 5	*n*	− 5
α	+ 1	δ	− 4	*k*	± 0	*q*	− 2
c	+ 5	ε	− 2	*l*	− 1	*r*	− 3
β	− 2	*f*	− 6	λ	− 3	*s*	− 5
μ	− 4	*g*	− 3	ζ	− 3	*t*	+0·002
d	+0·002	ψ_1 *Aq.*	+0·011	η	−0·006		

The agreement of the two discussions is very satisfactory.

The average weight of a star's right ascension, according to Professor Bakhuyzen, is 162 (in which weight 1· corresponds with a *mean error* of $\pm$ 0ˢ·111) ; hence the *mean error* in right ascension is $\pm0^{s}\cdot0087$.

My results give $\pm0''\cdot127$ as the average *mean error* of a star's place in declination. The *probable error*, therefore, is less than $\pm0''\cdot1$ of arc both in right ascension and declination. This result is due to the co-operation of so many Observatories, and the small probable error arrived at refers only to differences of right ascension and declination. The absolute right ascension is uncertain, as yet, to a much larger amount. The conclusions which may be drawn from the discussion appear to be as follows :—

1. In comparing different systems of clock stars, regard is too often paid only to the bright Fundamental Stars, which average second magnitude, whilst the average of the clock stars generally used is 4–5 magnitude. If there is a correction required depending on magnitude (and that appears to be abundantly proved), *the use of bright stars only in such discussions will lead to false results.*

2. There appears to be abundant evidence to show that, besides the errors depending on magnitude, there are others which can only be accounted for on the supposition of instrumental errors. That is to say, after corrections have been applied to reduce the clock stars to a uniform system, then the curves which represent the corrections due to magnitude should pass through $\pm0''\cdot000$ for stars of 4–5 magnitude (the mean magnitude of clock stars). A reference to the diagram will show that this is not the case.

Now the clock stars have, as a rule, considerably greater north declination than the *Mars* stars; hence a pivot error changing the azimuth and level at different altitudes, or a weakness of one side of the cube, producing a changing error of collimation, which reaches its maximum at the zenith, would produce a systematic difference in the places of the *Mars* stars as compared with the places of the clock stars.

Whilst I admit that these curves result from comparatively limited data, there still appear to be outstanding differences, which can only be accounted for by such errors as I have described. This points to *the necessity of more rigid determination of the errors of meridian instruments, particularly of the change of collimation at different altitudes;* a matter almost entirely neglected at present, and specially necessary in view of the increasing size of meridian instruments and their less frequent reversal.

3. The *personality depending on magnitude* requires more complete discussion. It *should be determined for each observer, and this determination ought to be as rigidly looked to as the ordinary personal equation* is when different observers are employed at the same Observatory.

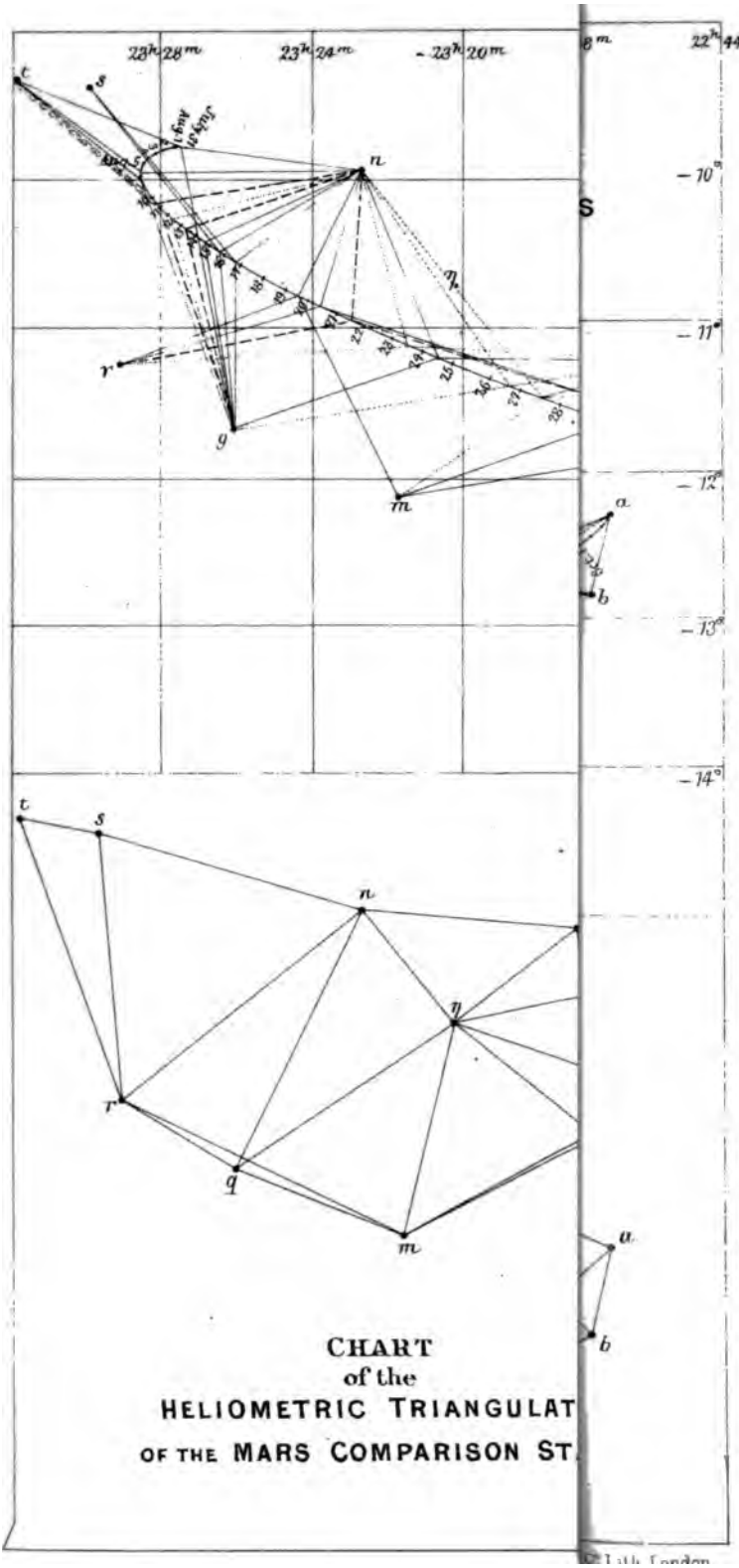
It can easily be accomplished as follows:—

A bright star is observed over the first five wires; a diaphragm is applied in front of the object-glass (by which the star is reduced a known number of magnitudes in brightness), and the star is then observed over the last five wires. These transits, on being reduced to the middle wire give the personality due to difference of magnitude. Another observation, in which the operation is reversed (the diaphragm being used with the first five wires, the full aperture with the last five), eliminates the possible change of collimation which may be supposed to arise from the application of the diaphragm, and also eliminates errors in the assumed wire intervals.

It was in this way that Professor Bakhuyzen determined for his assistants' observations in right ascension the corrections which I previously quoted. It is somewhat remarkable that for all three assistants a negative correction of their results in right ascension is required for the fainter stars.*

It is still more remarkable, however, if confirmed by more extended experiment, that, as a rule, when chronographic registration is employed, the required correction to the observed right ascension of faint stars is −, and when eye and ear observations are employed it is +. It is most satisfactory to find this law coincides with the explanation I attempted to give

* Argelander employed what is in some respects a better method, observation of the right ascensions of the variable stars. The method advantage that the determination of personality is made in the ordinary of regular observation, but it can only be employed by an enthusiastic carrying on a long and well sustained series of observations with purpose.


23h 28m
23h 24m
23h 20m
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− 10°
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CHART
of the
HELIOMETRIC TRIANGULAT
OF THE MARS COMPARISON ST

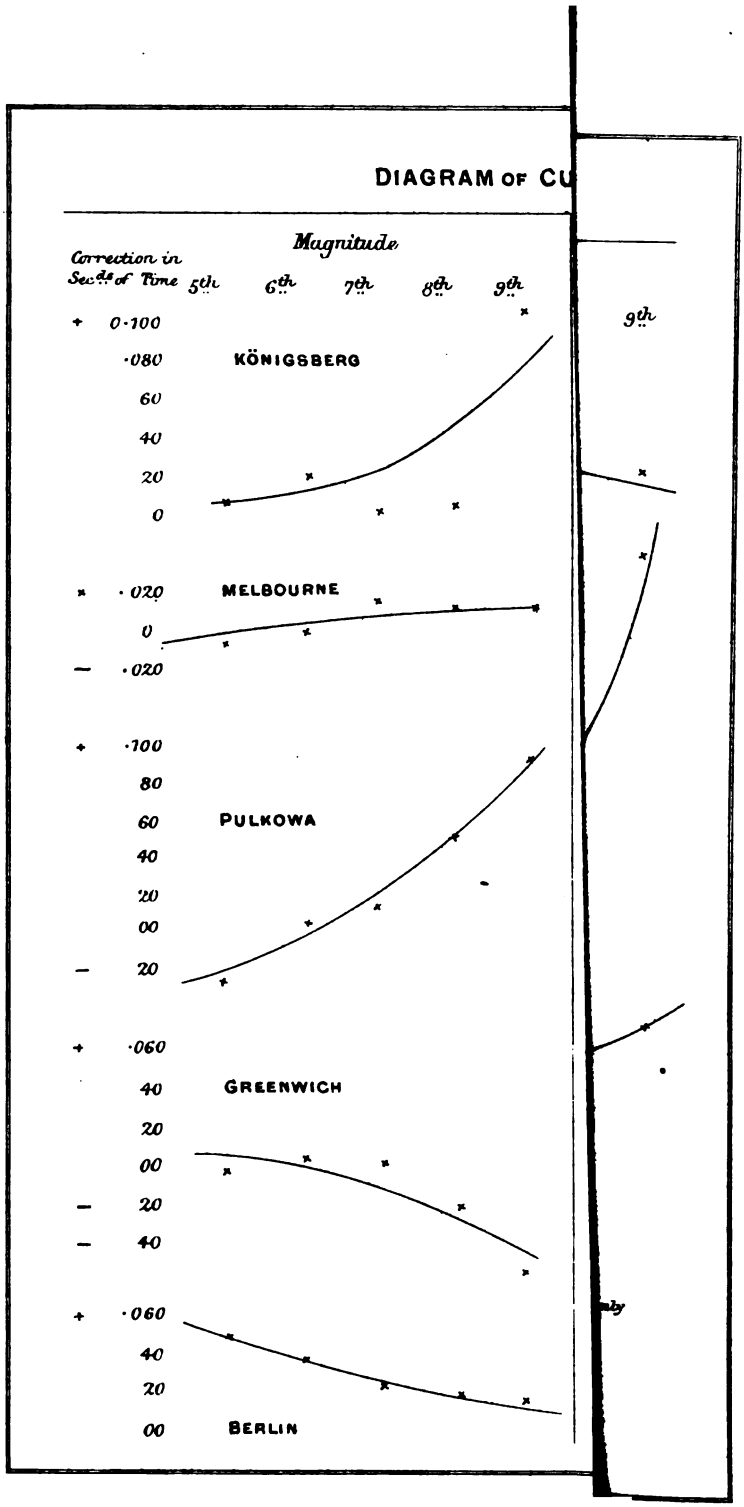
DIAGRAM OF CU
Magnitude
Correction in Secds of Time
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6th
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9th
+ 0·100
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KÖNIGSBERG
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to the physical cause of the personality in question, viz. that in chronographic registration the tendency will be to press the key too late for faint stars, because their small neat disks make them appear further from the web than a bright star with its larger disk and rings at the same angular distance from the web.

I think it, therefore, not improbable that there may still remain systematic errors depending on magnitude in the right ascensions which have been deduced in the present discussion. The comparison with the heliometer measures will, however, probably settle the question.

The accompanying diagram shows the measures that have been made in the triangulation, and will enable the reader to form some idea of the geometrical conditions of rigidity which have been realised in the operation.

Another portion of the same plate shows similarly the measures from the stars to *Mars*.

A line thus ——— denotes both Morning and Evening Observations.

A line thus ..... Evening Observations only.

A line thus - - - - - - Morning Observations only.

On Observations of α Centauri made with the Heliometer at Ascension in 1877. By David Gill, Esq.

The following observations of the remarkable binary *α Centauri* were made during my stay at Ascension in the latter part of 1877. As I am frequently asked for the results of my measures of this object, I have thought it best to lay them before the Society without further delay.

The observations were not easy, as the following considerations will show.

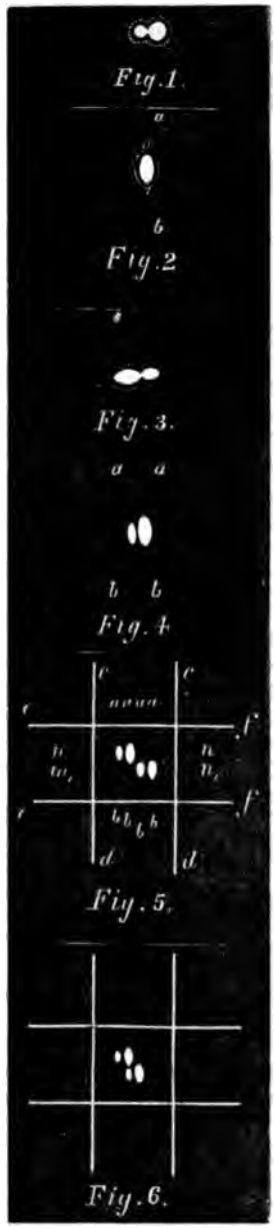
The image of an infinitely distant luminous point is a disk surrounded by rings; the diameter of this disk varies inversely as the aperture of the telescope. For a telescope of 4 inches aperture (that of Lord Lindsay's heliometer) this disk has a diameter of about 1″; in other words, a telescope of 4 inches aperture will barely separate a double star whose distance is 1″, the effect being to produce the appearance in fig. 1.

The half of a heliometer object-glass, however, produces a peculiar image of a single star, somewhat as in fig. 2.

Roughly speaking, it is an ellipse, whose axes are as 2 to 1, the smaller diameter being at right angles to the line of section of the object-glass, and the rings extending into a diffraction ray *ab*.

Now it happened that the first time I turned the heliometer upon *α Centauri* I found it, to all appearance, a single star rather ill defined, looking somewhat like a single star seen in a badly centred object-glass. The fact was, however, that the

heliometer happened to be set so that the position angle of the line of separation of the segments was nearly at right angles to the position angle of the star; the true effect was to produce the appearance shown in fig. 3, and the air being unsteady, the rings were mixed up with the disks in a puzzling way.



When, however, the position circle was set nearly to the true position angle of the stars, the effect became as in fig. 4, and in still moments the diffraction rings were well seen and also the fine diffraction lines *ab*, as in fig. 2.

It is evident that in such an image distances can be more accurately measured than position angles, and accordingly measures of the latter were made in greater number in order to give the results nearly equal accuracy with those from measures of distance.

In position-angle measures the observations were made as follows:—

In the field of view, and accurately adjusted to the plane of the principal focus of the objective, there was a square formed by fine flat gold wires *cd* and *ef* (fig. 5).

The wires *ef* were carefully adjusted to parallelism with the motion of the segments by setting the position circle to 90° + index correction, and allowing a star to run along the wires *ef*, or by placing a star on the edge of a wire and moving the segments rapidly to test if the star ran truly along its edge. This latter could be done almost independently of errors in the clockwork movement when the position circle was set to 90°.

This adjustment having been made, it was tested over and over again by both the methods described without my being able to improve it. I have therefore not attempted to apply any correction, and any error there may be in the coincidence of these wires with the motion of the segments is certainly very far within the accuracy

aimed at in the measure of position angle of so close a double star as *α Centauri*.

In making the measure of position angle the heliometer tube was turned in its cradle till the imaginary lines mn and m_1n_1 (fig. 5) seemed parallel with the lines ef. The imaginary lines mn, m_1n_1 are supposed to pass through the centres of the images formed by segment A and segment B of the object-glass respectively. The lines mn and m_1n_1 would of course coincide when parallel if the two segments could be adjusted so perfectly that their optical centres exactly coincided at least distance; that is to say, if the segments were so adjusted that the images of a single star produced by both segments could be exactly superposed by simple motion along the slides. Such an adjustment, even if once made, can never be long maintained, and during the observations at Ascension the error generally amounted to about 2″. Thus the appearance of the stars when measured for position angle was nearly as shown in fig. 5. Of course the segments were reversed in each measure, and after each bisection the setting was displaced and brought up in alternate bisections from opposite directions.

By use of the reversing prism all the observations were made with the stars apparently either vertical or horizontal, and in each set of four bisections (constituting one measure) two bisections were made in each of two opposite directions of the image; that is, two bisections were made with the brighter star apparently to the right or above, and two bisections with the brighter star apparently to the left or below. No systematic difference was found between the position angles measured with the stars vertical and horizontal.

An observation for position angle having been made, the circle was set to the mean of the four readings which constituted the measure in position angle when the stars were arranged as in fig. 5. By careful movement of the slow motion handle, taking advantage of steady intervals of definition, the four diffraction lines were arranged at equal distance from each other and the scales were read off; the segments were then reversed, and the process was repeated. Now the little reversing prism was rotated 180°, the latter operation repeated, and finally the first operation was repeated. In this way the double distance of the stars was measured. When the observations were made in daylight, however, the diffraction lines ab could not be seen, and I then thought it more exact to measure the single distance, as in fig. 6, with similar precautions. After all the instrumental corrections have been applied, the following are the results:—

Results of Measures of a_1 and a_2 Centauri at Ascension Island.

Date.	Distance.	No. of Obs.	Position Angle.	No. of Obs.	Remarks.
	"		° ′		
1877·559	2·220	1			
·568	2·128	1	80 31	3	
·592	2·055	1	80 29	2	
·617	...	...	80 38	4	
·628	1·942	2	82 1	4	
·642	...	...	81 49	4	
·800	1·937	2	...		Measures made with great difficulty from unsteady air.
·827	1·863	1	99 41	2	
·841	1·760	3	94 36	3	
·876	1·806	1	99 54	2	
·901	1·438	1½	102 11	2	Definition very bad.

Thus, in hardly more than four months, we have evidence of a change of fully 0″·5 in distance and 20° in position angle. In connection with these measures, it is interesting to hear from Mr. Ellery (*The Observatory* for August 1868) that, from observations on May 8 of the present year, the components are now separating. Obviously, then, the above measures have been made during a critical and important epoch in the orbit. I only regret that much other work prevented my making more numerous measures, including some on artificial stars.

Additions to Memoir on the Theory of the Sidereal System.

By Maxwell Hall, Esq.

There are a few more stars to be added to the lists given in the Memoir on this subject, vol. xliii. of the *Memoirs*, and there are several Notes to be made respecting stars already discussed. These additions are for the most part satisfactory, and confirm the Theory as formerly explained.

It may be remembered that the Sun and the nearer stars were assumed to revolve in circular orbits about their common centre of gravity, a point in space whose position was found to be—

	°		
R.A.	9	15	1850, Jan. 1·0,
N.P.D.	63	28	

and whose distance is 31 million times the distance of the Earth

from the Sun; that by means of these data, which were obtained by combining the direction of the Sun's motion through space with the proper motions and distances of *α Centauri*, 61 *Cygni*, and *Sirius*, the parallaxes and radial velocities of several other stars were computed from their observed proper motions; that the results of the comparison between observation and theory were highly satisfactory in several cases; but that for a few stars the results were decidedly wrong.

This peculiarity still exists, and four of the stars considered give erroneous results, possibly due to the assumed circularity of their orbits.

The following Table contains all the stars whose parallaxes have been found by observation; they are 23 in number; and the differences between observation and computation are exhibited as clearly as possible. The radial velocities are expressed in terms of mean radii of the Earth's orbit per annum; in order to express these velocities in miles per second, they must be multiplied by 2·9.

Star.	M.	Annual Parallax.			Radial Velocity.		
		Obs.	Comp.	O−C.	Obs.	Comp.	O−C.
		"	"	"			
α Centauri	0·6	0·936	0·936	0·000			
61 Cygni	5·5	0·438	0·422	+0·016			
Sirius	0·1	0·204	0·210	−0·006			
Arcturus	0·8	0·133	0·188	−0·055	−15·4	−14·5	−0·9
Vega	1·0	0·098	0·069	+0·029	−15·9	−17·5	+1·6
Procyon	1·0	0·123	0·074	+0·049	+ 9·7	+ 8·6	+1·1
Capella	1·0	0·046	0·029	+0·017	+ 9·7	+ 8·7	+1·0
Altair	1·3	0·181	0·146	+0·035	−13·3	−14·1	+0·8
70 *p* Ophiuchi	4·5	0·160	0·099	+0·061			
34 Groombridge	8·0	0·307	0·195	+0·112			
Polaris	2·3	0·068	0·008	+0·060			
85 Pegasi	6·0	0·050	0·071	−0·021			
3077 Bradley	6·0	0·070	0·104	−0·034			
η Cassiopeiæ	4·0	0·154	0·065	+0·089			
μ Cassiopeiæ	5·5	0·342	0·199	+0·143			
γ Draconis	2·6	0·092	0·007	+0·085			
β Centauri	1·2	?	0·001	...			
21185 Lalande	7·5	0·501	0·753	−0·252			
ι Ursæ Majoris	3·5	0·133	?	...			
1830 Groombridge	6·5	?	2·682	...			
σ Draconis	5·0	0·255	1·963	...			
17415 Oeltzen	9·0	0·247	neg.	...			
21258 Lalande	8·5	0·260	neg.	...			

It will be seen that out of these 23 stars there are two whose computed parallaxes are far too large, and that there are two whose parallaxes are negative; but on the other hand the close agreement between the observed and computed parallaxes and radial velocities of *Arcturus*, *Vega*, *Procyon*, *Capella*, and *Altair* excludes the possibility of such agreement being due to chance; and in forming equations of condition for the more accurate determination of the constants of the system it will be advisable to reject the discordances, and to give great weight to the agreements in both parallax and radial velocity.

But the time has not yet arrived for this redetermination; only six stars out of the 23 have been observed with the spectroscope; and although many of the stars are very small, others are large enough, as *Polaris*, γ *Draconis*, α and β *Centauri*, and a few more.

With regard to those stars which have been observed with the spectroscope, but whose parallaxes are as yet unknown, it might seem proper to compute their parallaxes and radial velocities for the sake of the comparison of the latter; but many of those stars have very small and therefore uncertain proper motions, and the few examples given in the memoir show that no great advance would be made. And indeed it will be better to delay all extensive calculations until the constants have been more accurately ascertained.

The following notes and computations refer to the details of the alterations and additions comprised in the above Table; they will be found useful in the reconstruction of the system.

α *Centauri*.

A valuable paper by Mr. Stone on the proper motions of southern stars will be found in vol. xlii. of the *Memoirs*, where the following are given for this star:—

P.M. in R.A. $= -0^s.485$

P.M. in N.P.D. $= -0''.75$.

As these proper motions agree very closely with those adopted in the Memoir, page 168, no recomputation was considered necessary for the present; but, for the future, the proper motions given by Mr. Stone should be employed.

61 *Cygni*.

In the *Observatory* for September 1878 Dr. Ball discusses a series of observations for parallax and finds $0''.465$. This is very satisfactory, and confirms the adopted value of $0''.422$. Dr. Ball also gives seven other determinations; if we include his own and take the mean of the eight, we shall find $0''.438$ as the probable parallax of this star.

Sirius.

The parallax of 0″·193 ascribed to this star by Professor Gylden has been generally adopted since the Memoir was written. We have therefore for this star

	″
Henderson, corrected by Peters	0·15
Abbe	0·27
Gylden	0·193
Mean	0·204

The radial velocity found by Dr. Huggins has been confirmed at Greenwich very recently. By giving the weights indicated in the Greenwich Table of "Motions of Stars in the Line of Sight," *Monthly Notices*, vol. xxxviii., p. 507, the radial velocity observed is +7·9; Dr. Huggins found +6·9; but as no correction can yet be made for the binary motion of *Sirius*, its radial velocity has been omitted in the above Table.

Arcturus.

The parallax of 0″·127 found by Peters was confirmed by the parallax of 0″·138 found by Johnson, *Monthly Notices*, vol. xvii., p. 271; a mean parallax of 0″·133 should be adopted.

Again, the recent observations at Greenwich give a radial velocity of −11·7; Dr. Huggins found −19·0; and the mean, −15·4, agrees very closely with the theoretical radial velocity of −14·5.

Vega.

It was shown that the probable value of the observed parallax was about 0″·09; and this is confirmed by Johnson' parallax of 0″·08, and by Brünnow's recent determination of 0″·13; a mean parallax of 0″·098 should be adopted.

For the radial velocity we have

Dr. Huggins	−17·0
Dr. Vogel	−17·9
At Greenwich	−12·8
Mean	−15·9

The theoretical value is −17·5.

Procyon.

A radial velocity of +9·7 has been observed at Greenwich; the theoretical velocity of +8·6 has therefore been confirmed.

Capella.

As for *Procyon*, a radial velocity of +9·7 has been observed at Greenwich; the theoretical velocity of +8·7 has therefore been confirmed.

Polaris.

A parallax of 0″·091 was adopted in *Nature*, 1876, November 23; and in the same periodical Professor Gylden adopted a parallax of 0″·046, 1878, October 24. And as Peters found 0″·067, the most probable value of the parallax is 0″·068.

It is to be regretted that *Polaris* has not yet been observed with the spectroscope for velocity in the line of sight.

85 *Pegasi.*

A parallax of 0″·05 has been found by Dr. Brünnow for this star; the proper motions used in the computations were taken from the B.A.C.

3077 *Bradley.*

A parallax of 0″·07 has been found by Dr. Brünnow for this star; the proper motions used in the computations were taken from the B.A.C.

η Cassiopeiæ.

A parallax of 0″·154 was assigned to this star in *Nature*; the proper motions used in the computations were found by Main.

μ Cassiopeiæ.

A parallax of 0″·342 has been found by Professor O. Struve; the proper motions, which are very large, have been taken from Main's paper.

γ Draconis.

The observations made at Greenwich gave a negative parallax to this star; a parallax of 0″·092 is given in *Nature*, Chambers's *Descriptive Astronomy*, and elsewhere. Main's proper motions have been employed; they are very small.

β Centauri.

In vol. xxi. of the *Memoirs* there is an elaborate discussion of the parallax of this star by Maclear, who reduced the whole series of observations in N.P.D. to the equation

$$\pi = 0''{\cdot}4817 + 0{\cdot}3987\,\mu,$$

where π is the annual parallax of the star and μ its proper motion in N.P.D., both expressed in seconds of arc.

Maclear found $\mu = +0''{\cdot}064$ at the commencement of that memoir; but afterwards he adopted $-0''{\cdot}03$ with no obvious reason, and so deduced a parallax of $0''{\cdot}47$; at the same time the constant of aberration became $20''{\cdot}59$.

This determination is unsatisfactory, and the star was not considered in the Memoir on the sidereal system; but as the parallax of $0''{\cdot}47$ has been adopted by two or three writers, it becomes necessary to include this star.

The proper motions according to Mr. Stone are $-0^s{\cdot}010$ in R.A. and $+0''{\cdot}05$ in N.P.D.; and by employing this value of μ, π becomes $0''{\cdot}502$; the computed parallax is insensible.

21185 *Lalande.*

A parallax of $0''{\cdot}501$ has been found for this star by Winnecke. The proper motions given by Lynn are $-0^s{\cdot}044$ in R.A. and $+4''{\cdot}66$ in N.P.D.

17415 *Oeltzen.*

This star gave a negative parallax, and I threw considerable doubt upon my own work because, in the *Astronomical Register*, vol. xiii., p. 272, it is referred to as 7515 Oeltzen, and a misprint seemed improbable. I have to thank Dr. Krüger for sending me a reprint of his article on the determination of the parallax of this star, which was published in the *Acta Soc. Scien. Fennicæ*, *t.* vii.

The star is Nos. 17415, 6 Oeltzen; and no alteration can be made at present in the former computations.

21258 *Lalande.*

An unfortunate mistake has occurred with respect to this star. Mr. Lynn confirmed the proper motions found by Professor Argelander, and in the *Monthly Notices*, vol. xxxiii., p. 102, he gave $-0^s{\cdot}386$ in R.A. and $-1''{\cdot}36$ in N.P.D. This was in December 1872; early in the year 1873, when I was abroad, I adopted his determinations as recorded in the *Astronomical Register*, vol. xi., p. 5, where the negative sign was unfortunately omitted before the proper motion in N.P.D. Consequently it was assumed that the proper motion was positive, and it is not a little remarkable that the erroneous computations gave a correct value of the annual parallax, while the correct computations give a negative parallax, which can only be considered as erroneous in the present state of the theory

No.	Star.	M.	R.A. h m s	P.M. in R.A. s	N.P.D. o ′	P.M. in N.P.D. ″
1	85 Pegasi	6·0	23 54 21	+0·067	63 43	+0·95
2	3077 Bradley	6·0	23 6 4	+0·201	33 40	−0·28
3	η Cassiopeiæ	4·0	0 40 3	+0·132	32 59	+0·49
4	μ Cassiopeiæ	5·5	0 58 19	+0·386	35 49	+1·56
5	γ Draconis	2·6	17 53 8	0·000	38 29	+0·04
6	β Centauri	1·2	13 53 17	−0·010	149 39	+0·05
7	21185 Lalande	7·5	10 55 8	−0·044	53 2	+4·66
8	21258 Lalande	8·5	10 58 0	−0·386	45 42	−1·36

No.	log *l*	log *m*	log *n*	log δ*l*	log δ*m*	log δ*n*
1	+9·95248	−8·34571	+9·64622	+ 9·64621	+ 9·94959	− 9·93033
2	+9·73165	−9·11145	+9·92027	+ 9·21245	+10·22531	+ 9·19095
3	+9·72924	+8·97630	+9·92367	+ 9·33646	+10·05423	− 9·42611
4	+9·75308	+9·16833	+9·90896	+ 9·56937	+10·55606	− 9·96042
5	−8·27049	−9·79380	+9·89364	− 6·97220	− 8·49551	− 8·39605
6	−9·64818	−9·37962	−9·93599	+ 7·30750	+ 8·94047	− 8·40250
7	−9·88491	+9·34856	+9·77913	−10·18865	+10·11025	−10·57093
8	−9·83864	+9·28163	+9·84411	+10·30600	+10·57276	+ 9·98827

No.	log *a*	*b*	*c*²	H	K	log (H+Hρ$_0$)	log (K+*a*HΠV)
1	+9·12070	−1·267	1·714	−0·9861	−0·139	− 9·95075	− 9·11394
2	+9·68843	−1·314	2·873	− ·8292	−0·455	− 9·88395	− 9·62634
3	+9·48940	−1·108	1·402	− ·8617	−0·236	− 9·88047	− 9·33445
4	+9·39005	−3·509	13·917	− ·8835	−0·438	− 9·92952	− 9·62531
5	+9·97598	+0·012	0·002	− ·2436	+0·016	+ 9·84905	+ 8·89763
6	−9·33546	−0·086	0·008	+ ·8127	−0·003	+10·73832	− 8·23045
7	+9·41984	−2·893	17·909	+ ·3768	+2·841	+ 9·58614	+10·45606
8	+9·52035	−2·821	19·020	+ ·2696	−2·759	...	−10·43727

No.	log *u*	HΠV	log $\left\{\begin{smallmatrix} au-b \\ +H\Pi V \end{smallmatrix}\right\}$	log *w*	$\frac{w}{u}$	ρ$_0$	$\frac{d\rho}{dt}$
1	+ 9·16319	−0·065	+10·08672	8·85303	0·071	14·03	− 2·04
2	+ 9·74239	− ·055	+10·18441	9·01865	0·104	9·58	− 5·29
3	+ 9·45398	− ·057	+10·05652	8·81490	0·065	15·31	− 4·36
4	+ 9·69579	− ·058	+10·55303	9·29945	0·199	5·02	− 2·49
5	+ 9·04858	− ·016	+ 8·89209	7·85075	0·007	141·01	−15·77
6	− 7·49213	+ ·054	+ 9·14922	7·15429	0·001	700 99	+ 2·18
7	+10·86992	+ ·025	+10·68726	9·87656	0·753	1·33	− 9·85
8	...	+ ·018	...	...	...	...	...

Errata in Memoir, vol. xliii.

Page 168, last line. For "0″·78" read "−0″·78."

„ 176, equation (10). For "$2V\{au-b+H\Pi V(1-\Lambda\}$" read "$2V\{au-b+H\Pi V(1-\Lambda)\}$."

„ 179, line 4. For "$\frac{d\rho}{d}$" read "$\frac{d\rho}{dt}$."

„ 185, line 20. For "south, preceding" read "south-preceding."

„ 191, line 3. For "0″·223" read "0″·023."

And in Tables &c., *dele* Star No. 10 and substitute from the Tables in the present article Star No. 8.

Reduction of the North Polar Distances of the Cape Catalogue for 1860 to Auwers' Standard. By A. W. Downing, B.A., T.C.D.

When comparing Catalogues together for such purposes as the determination of proper motions, it is of course necessary, where extreme accuracy is desired, to reduce the places of stars given in the different Catalogues to a uniform standard, so that the discordances peculiar to each individual Catalogue may be thus eliminated. The standard usually adopted for North Polar Distances is that given by Dr. Auwers in No. 1536 of the *Astronomische Nachrichten*, and in the present paper I have investigated the corrections which it is necessary to apply to the N.P.D.'s of the Cape Catalogue for 1860 to reduce them to this standard.

The Cape Catalogue has first been compared with the Greenwich Seven-Year Catalogue for 1860. There are 385 stars common to the Catalogues which are available for the purpose, after rejecting those whose places in either Catalogue depends on a single observation, and also two other stars, one passing the meridian very near the horizon of the Cape, and whose N.P.D. in the Cape Catalogue depends on only two observations, the other passing the meridian very near the horizon of Greenwich, the place in the Greenwich Catalogue depending on the same limited number of observations. These 385 stars have been arranged in order of N.P.D. and have then been taken in groups, each embracing about 5° of N.P.D., and, by taking the means of the N.P.D.'s and of the differences between the Catalogues for each group, I get 16 sets of mean differences extending from N.P.D. 49° 51′ to 124° 34′. These differences have been laid down and a curve drawn through the points which may be taken as representing the systematic differences between the Catalogues. The following Table gives the differences as computed and as read off from the curve.

N.P.D.		Number of Stars.	Gr. − C.	
			Computed.	Curve.
°	′		″	″
49	51	4	+0·52	+0·58
57	48	5	+0·43	+0·53
62	43	21	+0·29	+0·50
67	44	36	+0·60	+0·48
72	24	20	+0·33	+0·45
77	29	25	+0·55	+0·38
82	32	27	+0·41	+0·33
87	26	25	+0·14	+0·31
92	30	25	+0·20	+0·38
97	44	31	+0·56	+0·42
102	56	15	+0·24	+0·39
107	35	38	+0·45	+0·33
113	2	25	+0·05	+0·24
117	19	47	+0·26	+0·17
121	33	28	+0·02	+0·12
124	34	13	+0·23	+0·20

The differences have then been read off from the curve for every 4°, beginning from N.P.D. 48°, and, by applying the corrections to the Greenwich N.P.D.'s given in Dr. Auwers' paper before referred to, the corrections applicable to the Cape N.P.D.'s to reduce them to the standard have been obtained. The results are given in the following Table :—

N.P.D.	Gr. − C.	Standard − Gr.	Standard − C.
°	″	″	″
48	+0·59	−0·21	+0·38
52	+0·57	−0·30	+0·27
56	+0·54	−0·39	+0·15
60	+0·51	−0·38	+0·13
64	+0·48	−0·40	+0·08
68	+0·46	−0·44	+0·02
72	+0·45	−0·47	−0·02
76	+0·41	−0·49	−0·08
80	+0·35	−0·41	−0·06
84	+0·31	−0·29	+0·02
88	+0·34	−0·22	+0·12
92	+0·37	−0·18	+0·19
96	+0·41	−0·16	+0·25
100	+0·41	−0·19	+0·22
104	+0·37	−0·29	+0·08

N.P.D. °	Gr.−C. ″	Standard−Gr. ″	Standard−C. ″
108	+0·30	−0·36	−0·06
112	+0·26	−0·47	−0·21
116	+0·20	−0·36	−0·16
120	+0·13	−0·38	−0·25
122	+0·13	+0·9	+1·0
124	+0·18	+1·4	+1·6

For the southern stars whose N.P.D.'s are greater then 120° I have compared the Cape Catalogue with Henderson's Catalogue of 172 stars published in the 10th volume of the *Memoirs*. Dr. Auwers uses the latter as a provisional standard for southern stars, as it appears from his investigation that, up to the zenith of the Cape, it does not differ much from his standard. The epoch of Henderson's Catalogue is 1833·0, and the places of the Cape Catalogue have been brought back to this date, using the precessions, secular variations, and proper motions given in the Catalogue, except in the case of *β Columbæ*, for which I have used the proper motion given in the Melbourne General Catalogue for 1870 instead of that given in the Cape Catalogue, which is taken from the B.A.C. It has been assumed that Henderson has corrected his places for the proper motion corresponding to the fraction of the year; but this is not quite certain; he does not give either the mean date of observation or the adopted proper motion. However, as his observations only extend from May 1832 to May 1833, the correction is insignificant, except in the case of a few stars having large proper motions. I have used 67 stars which are common to the Catalogues, situated between N.P.D. 115° and the South Pole; and proceeding in the same manner as for the northern stars, I get the following Table:—

N.P.D. °	″	Number of Stars.	H−C. Computed. ″	H−C. Curve. ″
117	34	4	+0·74	...
123	47	5	+1·04	+0·96
128	24	5	+0·47	+0·53
132	3	9	+0·24	+0·23
137	51	7	−0·40	−0·21
143	2	3	−0·16	−0·10
147	50	9	+0·19	0·00
152	51	6	−0·37	−0·12
157	40	4	+0·13	−0·13
167	7	3	−0·21	−0·15
172	52	5	−0·28	−0·24
178	26	7	−0·21	−0·22

The difference of the N.P.D.'s of these two Catalogues, as given above, are much more irregular than those of the Cape and Greenwich Catalogues; but this is no doubt owing to the inaccurate values of the proper motions of the southern stars which have been used. Mr. Stone considers that these proper motions may be 0″·02 or 0″·03 in error, which of course in 27 years would amount to a perceptible quantity. However, I have no doubt that the curve represents very fairly the systematic differences between the Catalogues as given by these observations.

As it might be considered that there were not sufficient materials for a trustworthy direct comparison between Henderson and the Cape Catalogue, I have also compared them indirectly by means of Johnson's St. Helena Catalogue. There are 202 stars available for the comparison of Johnson with the Cape, and Dr. Auwers has given the reduction of Johnson to Henderson derived from 149 stars. Johnson has not corrected his places for proper motion, except in a few instances given in the Notes, and has not given the mean dates of observation except in these cases. But as the observations extend from Nov. 1829 to April 1833 and are reduced to 1830·0, it has been assumed that 1832·0 may, in the mean, be taken as the mean date of observation, and 2 years' proper motion has been applied to every star, and then the place in the Cape Catalogue has been brought back to 1830·0. The result of the comparison is—

N.P.D.		Number of Stars.	J−C.	
			Computed.	Curve.
°	′		″	″
122	17	34	+0·63	+0·52
127	27	26	+0·68	+0·77
132	19	26	+1·00	+0·69
137	31	23	+0·01	+0·42
142	51	14	+0·74	+0·51
147	32	19	+0·65	+0·50
152	27	15	−0·32	+0·19
156	51	20	+0·55	+0·38
162	37	5	+0·67	+0·52
168	10	7	+0·26	+0·33
172	55	5	+0·24	+0·31
177	55	8	+0·47	+0·39

By applying Dr. Auwers' reduction of Johnson to Henderson and taking the mean of the direct and indirect comparison of Henderson and the Cape Catalogue, the final Table of reduction becomes—

N.P.D.	H−C.		
°	Direct.	Indirect.	Mean.
	"	"	"
120	+1·10	+1·37	+1·24
122	+1·05	+1·40	+1·23
124	+0·90	+1·43	+1·17
128	+0·60	+1·31	+0·96
132	+0·20	+0·85	+0·53
136	−0·09	+0·30	+0·11
140	−0·25	−0·05	−0·15
144	0·00	−0·09	−0·05
148	−0·01	−0·34	−0·18
152	−0·10	−0·78	−0·44
156	−0·15	−0·76	−0·46
160	−0·10	−0·54	−0·32
164	−0·08	−0·63	−0·36
168	−0·20	−0·73	−0·47
172	−0·23	−0·63	−0·43
176	−0·25	−0·35	−0·30
180	−0·23	+0·07	−0·08

Greenwich,
1878, *December* 9.

Professor Safford has kindly pointed out to me an *Erratum* in the proper motion in R.A. of 35 *Ceti*, as given in *Monthly Notices*, vol. xxxviii., p. 518. The corrected quantities are:

Mean Annual Motion	$+3^{s}\cdot0661$
Proper Motion in R.A.	−0·0142.

Greenwich,
1878, *December* 9.

Total Eclipse of the Sun, July 29, 1878.

By W. H. Pickering, Esq.

The eclipse was observed by me at Cherry Creek, two and a quarter miles south-west of Denver, Colorado. The instruments used were two Arago polariscopes (the same used by my brother, Professor E. C. Pickering, in 1869 and 1870) and a polarimeter lent me by Mr. Ranyard. The smaller polariscope consisted of a double-image prism and a selenite plate. It was twelve inches in length, one inch in diameter, and 4° 45′ field, giving red and

green colours. The larger polariscope was composed of a double-image prism and a quartz plate rotating to the left, giving blue and yellow. It was nineteen inches long, the quartz was one inch in diameter, and gave a field of 3°. The polarimeter consisted of two quartz wedges giving Savart's bands and a Nicol's prism, and these were neutralised by four crown-glass plates turning on a horizontal axis. The tube was nine inches in length and $\frac{3}{4}$ inch in diameter, giving a field of 4° 40′. The object of taking two Arago polariscopes was that the larger one, in 1869 in the hands of my brother, and in 1870 with Mr. W. O. Ross, had shown the corona wholly unpolarised, while the smaller instrument, at the same eclipse in 1870 with my brother, had shown the corona polarised radially. By taking both instruments and using first one and then the other, I hoped to obtain a clue to these contradictory results. Prior to the eclipse, in order to practise myself in observing radially polarised light, I had imitated this condition by laying a glass funnel on a looking glass, and reflecting the light of the sky through it. The light was thus strongly polarised—tangentially, however, instead of radially; but the effect was the same, only with the colours reversed. The artificial corona was thus seen surrounded by the blue background of the sky, which gave the usual polarisation.

The instant totality came on I observed the corona through the selenite polariscope, and found it radially polarised, but the colours were rather faint. They were the same above and below and complementary on either hand. I next took up the larger polariscope, and obtained a similar result. The right-hand image with vertically polarised light is blue when a mark upon the tube of the instrument is held uppermost. In this case, however, the right-hand image of the corona was green above and below and red on either hand, no other colours being visible. I next swept the instrument around the sky about 40° above the horizon. In determining the plane of polarisation I revolved the tube about its own axis until the image to the right of the mark attained its characteristic blue, and the other the characteristic yellow tint; the plane of polarisation then passed through the line separating the two images. The Sun at this time was nearly due west and about 40° above the horizon. When the instrument was pointed north and at the same altitude as the Sun the polarisation was nearly horizontal, and seemed to lie in a plane passing through the Sun. When pointed to the south I obtained the same result. I was surprised not to find it vertical, and repeated both observations, but with the same result. On pointing the instrument east I found the polarisation vertical, but could distinguish none whatever at the zenith. I looked very carefully at this point. I next took up the polarimeter and observed the sky about 10° to the right of the Sun and also 10° below it. In the hurry of the moment I held the instrument vertically, instead of first bringing the bands to a maximum and

then neutralising them with the glass plates. At 10° to the right I found the lines disappear when the plates were inclined 8°. At 10° below the lines were faintest at 2°.

I noticed that the night hawks came out shortly before totality and disappeared soon after. Just as totality was over I observed a number of shadowy bands on the ground. They were about a yard broad and two yards apart, and had a slightly wavering motion. They were very conspicuous and lasted nearly a minute. These estimates were made from memory immediately after the bands had disappeared.

In order to account for the colours as seen through the quartz polariscope, I have investigated the subject further by means of my funnel and mirror. I have found that when the light is only slightly polarised the blue and yellow, although in broad sectors, are not so conspicuous as the red and green, and that the green in the left-hand image, although not distributed vertically, is more nearly so than it is horizontally. My observation, if interpreted rigorously, would indicate a polarisation something between radial and tangential; but inasmuch as the colours were very faint, a slight variation on one side or the other of the vertical would hardly have been noticed, and I think it is safe to regard the result as denoting slight radial polarisation.

It is rather difficult to interpret my observations on sky polarisation. If we could discard the north and south observations, they would indicate radial polarisation from the zenith as a centre. On the other hand, accepting these and discarding the zenith observation, we have radial polarisation from the Sun. Finally, accepting these three as correct and disregarding the east observation, we have the sky horizontally polarised. The best interpretation which occurs to me is to suppose the sky not polarised merely from the zenith as a centre, nor merely from the Sun, but from both. In this case the polarisation in the east would be marked, which was true; in the zenith and in the neighbourhood of the Sun it would be very faint (the latter is shown by my polarimeter observations); and in the north and south the plane would lie neither in the direction of the zenith nor of the Sun, but somewhere between the two. In regard to my polarimeter observations: taking the one made 10° to the right of the Sun, it is evident that there was no perceptible horizontal polarisation or the lines would not have disappeared; and the vertical polarisation, if any, must have been very slight, as indicated by the number of degrees. The second observation, made 10° below the Sun, indicates no vertical, and perhaps very slight horizontal, polarisation.

Note by the Astronomer Royal on a Determination of the Mass of Mars.

Professor Asaph Hall, in his admirable paper on the satellites of *Mars*, after announcing his first inference in regard to the value of the mass of *Mars*, $\frac{1}{3107713}$, has cited the values $\frac{1}{1846082}$, $\frac{1}{2546320}$, $\frac{1}{2680337}$, $\frac{1}{3200900}$, $\frac{1}{2994790}$, $\frac{1}{2812526}$, successively adopted by Laplace, Delambre, Burckhardt, Hansen and Olufsen, and Le Verrier (Le Verrier has used the two last stated). I have not been able to trace the investigations on which these numbers are founded.

But I may perhaps call attention to an investigation made by myself, fifty-one years ago, published in the *Philosophical Transactions* for the year 1828. It is one of the results of a discussion of 10½ years' Greenwich observations of the Sun, from 1816, July 30, to 1826, December 30. The number of observations (from which all observations made under unfavourable circumstances have been eliminated) is 1,212. The result for the mass of *Mars* is $\frac{1}{3734602}$.

The Memoir in the *Philosophical Transactions*, 1828, to which I have alluded above, has not, apparently, met the eye of our transatlantic friends. As illustrating the progress of science in defining the place of the Sun and the masses of planets and Moon, it may perhaps be worthy of a short abstract at the present time.

In the year 1827 the attention of the Board of Longitude was called (in the first instance by Mr., afterwards Sir James, South) to the state of the Solar Tables used in the *Nautical Almanac*; and I, as a member of that Board, undertook the task of comparing the tables with observations; and a mass of more than 1,200 transits of the Sun, with stars, was placed in my hands by the then Astronomer Royal, Mr. Pond. For the method of discussing these I refer to the *Philosophical Transactions*, 1828. The principal results were the following:—

The mass of *Mars* adopted by Delambre was reduced in the proportion of 9 : 5 nearly. (It is to be remarked that the perturbations produced by *Mars* are small.)

The mass of *Venus* was somewhat reduced, and the value thus obtained agrees sensibly with that now adopted.

The mass of the Moon was reduced from $\frac{1}{60}$ nearly to $\frac{1}{80}$ nearly, a value now universally adopted. I do not remember whether any preceding investigation had led to a similar result.

Corrections were found for the excentricity of the Earth's orbit and for the place of perihelion.

A correction was found for the epoch of Sun's longitude; and this correction led to a result of some importance. The comparison of this with similar corrections found by Burckhardt for other epochs convinced me that there was an unrecognised inequality in the Sun's longitude, and finally led to the discovery of the equation of long period in the motions of the Earth and *Venus*.

To these results applying to the movable bodies of the solar system, I may add one which affects the honour of the Royal Observatory as maintained by my predecessor, Mr. Pond, that the whole train of the investigations testifies strongly to the excellence of the transit observations made sixty years ago, which appear to have been as good as those of the present day.

1878, *November* 16.

On the Conjunction of Mars and Saturn, 1879, June 30.

By Sir G. B. Airy, Astronomer Royal.

On 1879, June 30, will occur a conjunction of *Mars* and *Saturn* of unusual interest. Adopting the elements of the *Nautical Almanac*, Mr. Dunkin, at my request, has computed the geocentric places of the centres of the two planets for every hour—and through the greater part of the time for every quarter-hour—from June 30, 2^h to 20^h. The results for every quarter-hour, from 6^h to 9^h Greenwich Mean Solar Time, are laid down in a chart, which I have the pleasure of submitting to the Society. The small movements of *Saturn* are there applied, in opposite directions, to the true movements of *Mars*; so that, with a fixed representation of *Saturn*, the relative position of *Mars* is correctly given for each of those times. The magnitudes of the two planets and the position of *Saturn's* ring are accurately represented, the lower line of the chart being parallel to the Equator.

It will be seen that the nearest approach of the two planets occurs at $7^h\ 30^m$ nearly, and that the distance between their centres is then $1'\ 12''$. These numbers will be affected by the possible errors of the planetary tables.

In the table which accompanies the chart Mr. Dunkin has given the local times at Vienna, the Cape of Good Hope, Madras, Sydney, San Francisco, and Cordoba (Argentine Confederation), corresponding to the Greenwich hours above mentioned. (These stations are selected as giving a chain of longitudes proceeding easterly round the Earth, with some range of latitude.) The local times of planet-rise and sunrise are also given, as limiting the times of observation. It is mortifying to us to remark that the planets cannot be seen at their closest proximity in Europe

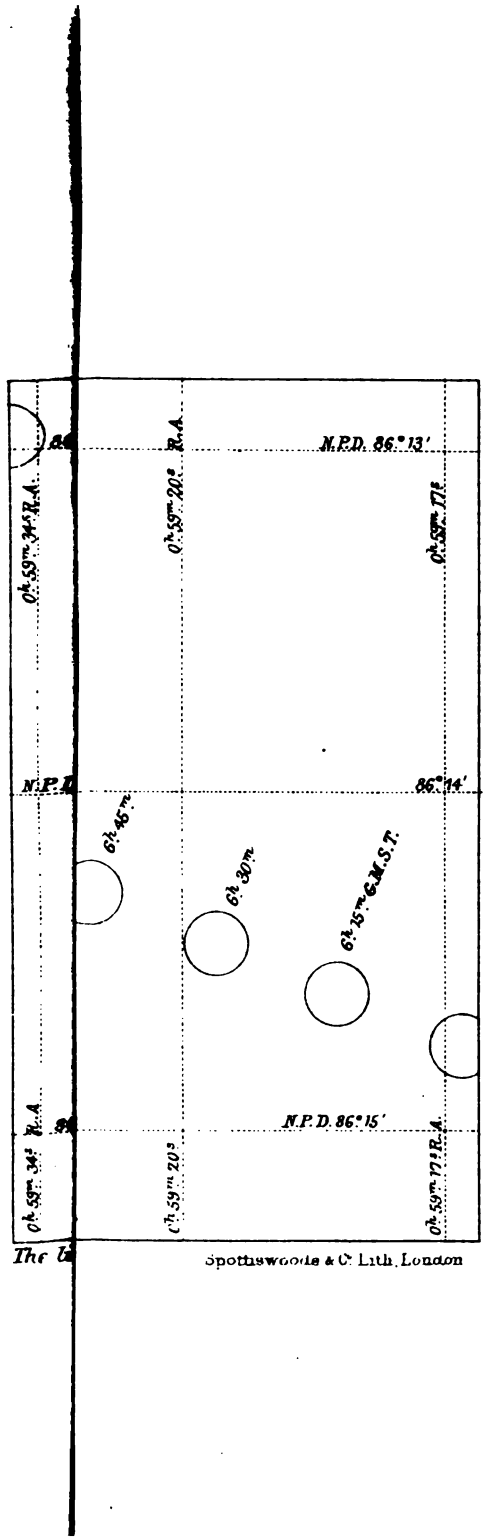
or Africa. For us the smallest interval will be about 9′. This, however, is less than the smallest interval at the conjunction of 1877, November 3. In India and Australia the conjunction will be seen extremely well. But no part of the near approach can be seen in America.

Different observers will make use of this phenomenon for different purposes. The instrumental measurement of the relative positions of the planets will give a test of Leverrier's Tables in parts of their orbits where it could not otherwise be obtained. I look with much interest to observations of the colours of the two planets. At the conjunction of 1877, November 3, the distance between the planets rendered it impossible to see them in the same field with a high power on the telescope, and therefore impossible to receive from them any large pencil of light. I did myself observe them with a good surveyor's hand-telescope, and was much struck with the result as to their colours. While *Mars* had his usual fiery yellow-red colour, *Saturn* was of deep sap-green. How much of this colour was due to contrast with the predominant blaze of *Mars* I cannot judge. In the approaching conjunction *Mars* will be much smaller, and the colours can perhaps be compared more justly.

I am permitted by Mr. Marth to state, as the result of his calculations of the places of the satellites of *Saturn*, that *Mars* will apparently pass through some of their orbits, and in particular will probably be within 30″ of *Japetus*. The nearest approach, however, will occur between 2^h and 3^h Greenwich Mean Solar Time, and probably can only be seen in some of the islands of the Pacific, as the Sandwich Islands or the Society Islands.

Mr. Marth also remarks that the position angle of the greatest defect of illumination of the disk of *Mars* on June 30, at 8^h, is 247°·08, and the greatest defect of illumination is 0·159 × diameter of the planet, or 1″·4, assuming the diameter as 8″·8.

Royal Observatory, Greenwich,
1878, December 7.



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Distances between the Centres of Mars and Saturn near their Conjunction on 1879, *June* 30, *for Local Times at Greenwich and seven other Observatories.*

Local Mean Solar Time at Greenwich.	Vienna.	Cape of Good Hope.	Madras.	Sydney.	San Francisco.	Washington.	Cordoba.	Distance of Centres of Planets.
June d h m	June d h m	June d h m	June d h m	June d h m	June d h m	June d h m	June d h m	′ ″
30 2 0	30 3 6	30 3 14	30 7 21	30 12 5	29 19 4	29 20 52	29 21 44	8 25
3 0	4 6	4 14	8 21	13 5	20 4	21 52	22 44	6 53
4 0	5 6	5 14	9 21	14 5	21 4	22 52	29 23 44	5 22
5 0	6 6	6 14	10 21	15 5	22 4	29 23 52	30 0 44	3 51
5 30	6 36	6 44	10 51	15 35	22 34	30 0 22	1 14	3 10
6 0	7 6	7 14	11 21	16 5	23 4	0 52	1 44	2 30
6 30	7 36	7 44	11 51	16 35	23 34	1 22	2 14	1 54
6 45	7 51	7 59	12 6	16 50	29 23 49	1 37	2 29	1 37
7 0	8 6	8 14	12 21	17 5	30 0 4	1 52	2 44	1 24
7 15	8 21	8 29	12 36	17 20	0 19	2 7	2 59	1 15
7 30	8 36	8 44	12 51	17 35	0 34	2 22	3 14	1 12
7 45	8 51	8 59	13 6	17 50	0 49	2 37	3 29	1 17
8 0	9 6	9 14	13 21	18 5	1 4	2 52	3 44	1 27
8 15	9 21	9 29	13 36	18 20	1 19	3 7	3 59	1 43

Distances between the centres of Mars and Saturn near their conjunction on 1879, *June* 30, *for Local Times at Greenwich and seven other Observatories*—continued.

Local Mean Solar Time at Greenwich	Vienna	Cape of Good Hope	Madras	Sydney	San Francisco	Washington	Cordoba	Distance of Centres of Planets
June d h m	June d h m	June d h m	June d h m	June d h m	June d h m	June d h m	June d h m	′ ″
30 8 30	30 9 36	30 9 44	30 13 51	30 18 35	30 1 34	30 3 22	30 4 14	2 3
8 45	9 51	9 59	14 6	18 50	1 49	3 37	4 29	2 24
9 0	10 6	10 14	14 21	19 5	2 4	3 52	4 44	2 45
9 15	10 21	10 29	14 36	19 20	2 19	4 7	4 59	3 7
9 30	10 36	10 44	14 51	19 35	2 34	4 22	5 14	3 30
9 45	10 51	10 59	15 6	19 50	2 49	4 37	5 29	3 53
10 0	11 6	11 14	15 21	20 5	3 4	4 52	5 44	4 16
10 30	11 36	11 44	15 51	20 35	3 34	5 22	6 14	4 59
11 0	12 6	12 14	16 21	21 5	4 4	5 52	6 44	5 43
11 30	12 36	12 44	16 51	21 35	4 34	6 22	7 14	6 27
12 0	13 6	13 14	17 21	22 5	5 4	6 52	7 44	7 11
13 0	14 6	14 14	18 21	30 23 5	6 4	7 52	8 44	8 43
				July				
14 0	15 6	15 14	19 21	1 0 5	7 4	8 52	9 44	10 18

15 0	16 6	16 14	20 21	1 5	8 4	9 52	10 44	11 52
16 0	17 6	17 14	21 21	2 5	9 4	10 52	11 44	13 27
17 0	18 6	18 14	22 21	3 5	10 4	11 52	12 44	15 2
18 0	19 6	19 14	30 23 21	4 5	11 4	12 52	13 44	16 37
			July					
19 0	20 6	20 14	1 0 21	5 5	12 4	13 52	14 44	18 12
30 20 0	30 21 6	30 21 14	1 1 21	1 6 5	30 13 4	30 14 52	30 15 44	19 48

Local Mean Solar Time of Planet-rise.

30 12 5	30 12 7	30 12 34	30 12 23	30 12 32	30 12 13	30 12 13	30 12 34	

Local Mean Solar Time of Sunrise.

30 15 53	30 16 9	30 19 10	30 17 40	30 19 10	30 16 45	30 16 42	30 19 4	

On the Visibility of Stars in the Pleiades to the Naked Eye.

By Professor Winnecke.

I had lately to look over the *Historia Cœlestis Lucii Barretti*,* Augustæ Vindelicorum, MDCLXVI. There I found, on p. lxxxv., some observations of the *Pleiades* made 1579, December 24, by Moestlin† (afterwards preceptor of Kepler at Tübingen, then Diaconus at Baknang, in Wurtemberg), which are very interesting, forming indeed the *first* special catalogue of this important cluster. In the excerpta of the manuscripts of Moestlin, made by Shickard and printed by Curtz in his *Historia Cœl.*, we find the following statement.

"1579, December 24, *Plejades* ita reperit. Declinationem primæ 22° 32′, secundæ 22° 52′, tertiæ 22° 48′, quartæ 22° 23′, quintæ 22° 36′, sextæ 22° 37′, septimæ 22° 38′, octavæ 22° 42′, nonæ 22° 57′, decimæ 23° 12′, undecimæ 22° 4′. Ascensiones rectas illarum numeravit à prima, scilicet secundæ 7′, tertiæ 16′, quartæ 22′, quintæ 39′, sextæ 1° 0′, sept. 59′, octavæ 2′, nonæ 15′, decimæ 359° 58′, ultimæ 42′."

There is also given a coarse woodcut representing the stars, which it is not worth while to reproduce because it contains several obvious mistakes, probably due to the circumstance, that in the woodcut only 10 stars are given, whilst 11 were observed by Moestlin. It is possible that Moestlin has *seen* so many as 14 stars with the naked eye; for Kepler, in his *Dissertatio cum Nuncio Sidereo* (*Opera Collecta*, vol. ii. p. 500) relates, "Moestlinus majusculas in Plejadibus ordinaria numerat, nisi fallor, 14."

Employing Moestlin's *measures*, we get the following map of the stars seen by him in the *Pleiades*, 1579, December 24 (see p. 148).

There is no difficulty in identifying these stars as the following in Bessel's Catalogue:—

	m		m
1 = Electra	4·5	7 = Plejone	5·6
2 = Taygeta	5	8 = Celæno	5·6
3 = Maja	5	9 = 21 *k* Plej.	7·8
4 = Merope	5	9 = 22 *l* „	7·8
5 = Alcyone	3·4	10 = 18 *m* Plej.	7
6 = Atlas	4·5	11 = Anon Bess. 25	8·9
		11 = Anon Bess. 26	9

Reducing Bessel's places of these stars to 1580·0 without proper motion, which, for our purpose, may be considered the same for all stars of the cluster, we get:—

* Anagram of Alberti Curtii, the Latin name of the Jesuit, Albert Curtz, 1671.

† Michael Moestlin, born 1550, September 30, at Göppingen; died 1631, December 20, at Tübingen.

		R.A. 1580·0.		Decl. 1580·0.		M—B.	Error.
		°	′	°	′	′	′
1	Electra	50	2·1	+22	42·6	+10·6	+0·8
2	Taygeta	50	6·2	23	4·0	12·0	+2·2
3	Maja	50	15·6	22	58·3	10·3	+0·5
4	Merope	50	24·0	22	33·4	10·4	+0·6
5	Alcyone	50	40·8	22	43·4	7·4	−2·4
6	Atlas	51	5·4	22	41·1	4·1	−5·7
7	Plejone	51	5·5	22	46·1	8·1	−1·7
8	Celæno	50	0·6	22	53·1	11·1	+1·3
9	$\frac{21k+22l}{2}$	50	17·5	23	8·8	11·8	+2·9
10	$18m$	50	4·7	23	26·3	14·3	+4·5
11	$\frac{\text{An. } 25+\text{An. } 26}{2}$	50	44·7	22	11·8	7·8	−2·0

The column M—B contains the difference between the declinations of Moestlin and Bessel; the last column the outstanding error after applying a constant correction of +9′·8 to the former.

Putting the R.A. of *Electra* = 0, we get the difference in R.A.

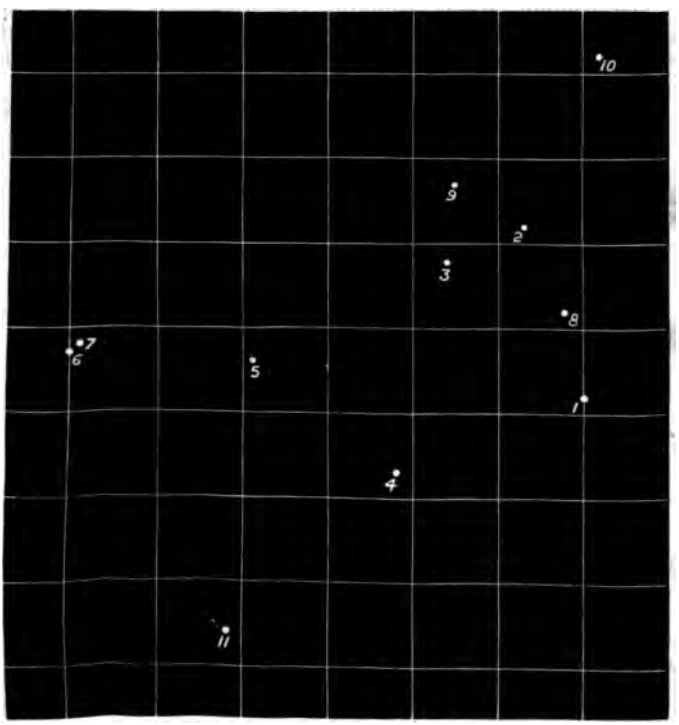
	Bessel.	Moestlin.	M—B.
	′	′	′
(2)−(1)	+ 4·1	+ 7	+2·9
(3)−(1)	13·5	16	+2·5
(4)−(1)	21·9	22	+0·1
(5)−(1)	38·7	39	+0·3
(6)−(1)	63·3	60	−3·3
(7)−(1)	+63·4	59	−4·4
(8)−(1)	− 1·5	2	+3·5
(9)−(1)	+15·4	+15	−0·4
(10)−(1)	2·6	− 2	−4·6
(11)−(1)	+42·6	+42	−0·6

The sum of the errors (each error as positive) is for Decl. 23′·7, for R.A. 22′·6. The probable error of a difference of R.A. or Decl. is therefore nearly the same and about ±2′.

The method used by Moestlin in getting his observations is not stated, but it is probable that the measures were taken by a Radius astronomicus just finished by his own hands. In the excerpta occurs the following statement:—"Medio Decembris (1579) fabrefecit radium observatorium, quo prius uti noluerat propter lubricitatem utendi. Sed quia vidit infixarum locis tot errores, fabrefecit. Nil enim prosunt planetarum observationes, si fixarum situs falsi sunt. Ea fuit causa, quæ decepit canonis planetici autores etc.; has prius reformare debuissent. Regulam

sumpsit 14 pedes longam, dividens in 14 particulas, et aptavit diversa transversaria partium 10, 16, 20, 32, 40, 60, 80, 100, 160, 200, 300, 400, 600, 800, iis pinnacidia junxit ad extremitates. Regulæ ipsi prope oculum infixit cuspidem certius collinandi gratia."

The little catalogue, given above, appears to be of some importance. Moestlin made it at a time *when no telescope had given evidence* that there are a great many stars in the *Pleiades*. The accuracy of their relative places is truly astonishing in so difficult an object. It is most interesting to compare the chart of the *Pleiades* founded on Moestlin's measures with that given by the Astronomer Royal (*Monthly Notices*, vol. xxiii. p. 175). Ten of the stars seen by both observers are identical without a doubt, and perhaps the 11th star is also the same as that seen at Greenwich, with a large error in Moestlin's measures. The 12th star seen at Greenwich is possibly also shown in the coarse woodcut mentioned above.



Strassburg,
1878, *December* 3.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXIX. *January* 10, 1879. No. 3.

Lord LINDSAY, M.P., F.R.S., President, in the Chair.

Lieut. C. W. Baillie, R.N., Imperial Naval College, Yedo, Japan;
Fredk. William Clerke, Esq., 1 Royal Exchange, E.C.;
Thomas Cushing, Esq., Woodstock Villa, Alexandra Road, Croydon;
Robert T. A. Innes, Esq., Campsbourne, Hornsey, N.;
Rev. John Holdsworth Morgan, St. Augustine, Honor Oak Park, S.E.;
Charles Pendlebury, Esq., B.A., St. Paul's School, E.C.;
Prof. C. W. Pritchett, M.A., Morrison Observatory, Glasgow, Missouri, U.S.A.;
Capt. James Rankin, Orchard Villas, Queen's Road, Forest Hill; and
Prof. Arthur W. Wright, Yale College, U.S.A.;

were balloted for and duly elected Fellows of the Society.

Prof. Asaph Hall, United States Naval Observatory, Washington, U.S.A.;
Prof. A. Krueger, Observatory, Gotha;
Prof. C. H. F. Peters, Clinton, U.S.A.;
Prof. H. C. F. C. Schjellerup, Observatory, Copenhagen;

were balloted for and duly elected Associates of the Society.

On the General Solution of the Problem of Disturbed Elliptic Motion. By E. Neison, Esq.

There are two distinct methods of dealing with the problem of disturbed elliptic motion. One method is to throw the effect of the perturbations directly on the three coordinates, or to suppose that the disturbed body moves in an irregular curve which is

approximately of the form of an ellipse. The other method is to throw the perturbations directly on the elements of the elliptic orbit, by assuming the body to move in an ellipse which is perpetually changing in form and position. The first method may be called that of perturbed coordinates, and has the advantage of requiring only three variables, but in turn the disadvantage of employing more complex differential equations. The second method, which may be termed that of perturbed elements, has the disadvantage of requiring six or seven variables, but requires a very much simpler form of differential equations.

What is required for astronomical purposes is the polar coordinates of the disturbed body. By making these polar coordinates the three variables of the first method, their values at any instant is at once obtained. But by the second method what is obtained is only the value of the elements of the ellipse in which the disturbed body is momentarily moving. These must be transformed into an expression for the required polar coordinates, and this necessitates extra work. Consequently there is this additional disadvantage in the method of perturbed elements.

Despite the disadvantages which have been pointed out, the method of perturbed elements is the simplest and most expeditious way of determining the perturbations of the order of the first power of the disturbing forces. For this reason it is admirably adapted for employment in the planetary theories, where powers of the disturbing forces are rarely required. In the lunar theory, however, it is absolutely essential to consider the square of the disturbing forces. But this renders most complex the known methods of determining the perturbations of the elements and necessitates an enormous increase in the labour. For instead of there being only six powers and products of the three variable coordinates, the second method involves the formation of no less than twenty-eight powers and products of the seven variable elements. The calculation of these powers and products is laborious and difficult. Therefore, under these conditions, the second method involves many times as much work as the first method.

For these reasons the earlier workers on the lunar theory —Damoiseau, Plana, Lubbock, Pontécoulant—employed the method of perturbed coordinates. The polar coordinates were taken for variables, and the differential equations were simplified by omitting all quantities of a higher order than it was intended to retain in the approximation, whilst by special artifices the amount of work was lessened. Poisson strongly advocated the method of perturbed elements, and, at his instigation, Pontécoulant employed it in certain parts of his lunar theory, but pointed out that to calculate the lunar inequalities by this method would be a work of immense labour. Hansen made use of a method which is really a modification of the method of perturbed coordinates, though he did not throw the perturbations directly

on the coordinates. In other respects his system of using his method was the same as that employed by his predecessors. In all these cases, therefore, special means were taken to obtain a solution which should be complete to a given order, but which could not be extended to any further order, and depended entirely on the special features of the problem. Lately, Hill, by making use of rectangular coordinates and a modified form of the differential equations, has successfully determined the value of the perturbations which are independent of the eccentricities. His method possesses some generality of form, and is not limited to the particular problem. It consists of an expression connecting together the different indeterminate coefficients. It is, however, an expression which gives a very complex form to the complete coefficient of the nth term, and is restricted to the coefficient of a small class of easy terms. Moreover, it yields the value of the rectangular coordinates and requires extra work to transform it into an expression for the polar coordinates. It is, however, to be remarked that for the definite purpose which its author had in view these are matters of indifference.

Delaunay, alone, has successfully made use of a method of throwing the perturbations on the elements of the elliptic orbit. He does not make use of the ordinary method of the variations of elliptic elements—that is, the method which has been employed by Pontécoulant and Le Verrier in the planetary theories, or which was advocated by Poisson for use in the lunar theory. Delaunay devised a most ingenious method, which really consists in determining the value of the elements which will make the disturbing function assume a given form ; a form which enables him to directly integrate the resulting differential equations. It is a most elegant and ingenious method, but is far more complex than any other, and involves an enormous amount of work. It is no exaggeration to say that it involves thrice the amount of work which would have been necessary to obtain the same result by the use of Pontécoulant's method. It is, moreover, purely a special method, a method depending on a long series of particular transformations, and it would be impracticable to obtain by its means a general expression for the perturbations of the coordinates or elements. On the other hand, Delaunay's method has an important advantage over any method involving the use of indeterminate coefficients, as Hill's or my own ; it is possible to separately determine the value of each single term in the perturbations without its being necessary to determine any other.

It has long been my opinion that, by choosing suitable variables, and by transforming the differential equations in a proper manner, it would be possible to obtain a complete general solution of the problem of disturbed elliptic motion ; that is to say, a solution which would be so far general that it would be possible to write down the perturbations to the nth order of the disturbing forces, and be independent of any particular values of

the elements. Such a solution would be obtained if it were possible to form a simple expression for the complete perturbations of the order of the nth power of the disturbing forces. It seemed to me that if such an expression could be formed, it would be an important contribution to the theory of disturbed elliptic motion, and in particular to the lunar theory. For several years, therefore, it has been a problem which has engaged much of my attention.

It was not long before it was seen that though it would be possible to obtain an expression for the perturbations of the order of the nth power of the disturbing forces, yet it was evident that it would be very difficult to prevent this expression becoming very lengthy and complex. This difficulty has now been overcome, and a very simple expression has been found for the perturbations of the order of the nth power of the disturbing forces.

In the present paper I propose to give a short account of the principal results, sufficiently full to enable them to be understood; but the details and minor developments are deferred to a subsequent communication, when I propose to apply the results to some important points in the lunar theory.

Let αR be the disturbing function when the elements of the orbit have their instantaneous values x, y, z, X, Y, Z, the coefficient α being supposed to be a constant, and let the general term of R be denoted by

$$R \cos w = (A)\, x^F y^G z^H \cos\{(\lambda) + fX + gY + hZ\}. \qquad (1)$$

where (A) and (λ) are supposed to be independent of the elements of the orbit, and to be absolutely constant.

Suppose R to denote the value of R when the elements have their constant mean values. Then R will be the same function of the mean elements, x, y, z, X, Y, Z, as R is of the instantaneous elements, x, y, z, X, Y, Z, so that the general term of R can be written in the form

$$R \cos w = (A)\, x^F y^G z^H \cos\{(\lambda) + fX + gY + hZ\}. \qquad (2)$$

Let each element of the orbit be considered as the sum of its constant mean value, and either of a single periodical function which represents its perturbations, or of n periodical functions which collectively represent its perturbations, so that, for instance,

$$x = x + \delta x = x + \delta_1 x + \delta_2 x + \ldots\ldots + \delta_n x = x + \Sigma \delta_m x. \qquad (3)$$

Then R is to be developed in terms of R and these variables, which represent the perturbations of the six elements.

Let v be taken as the general representative of the three elements which have been denoted by x, y, z, and I for the representative of the corresponding coefficients F, G, H: and similarly suppose V to represent the elements which have been denoted by

X, Y, Z and i to represent the corresponding coefficients f, g, h. Then it may be supposed that

$$\mathrm{v} = v + \delta v = v + \Sigma \delta_m v, \qquad \mathrm{V} = V + \delta V = V + \Sigma \delta_m V, \tag{4}$$

where δv, δV represent the periodical perturbations of the elements whose mean values are represented by v and V. Assume further that

$$\begin{aligned} v^{-1}\delta v &= \Sigma c_p \cos \gamma_p, & \delta V &= \Sigma \mathrm{C}_p \sin \gamma_p, \\ v^{-1}\delta_m v &= \Sigma j_p^m \frac{\mathrm{I}}{w_p} R_p^m \cos w_p, & \delta_m V &= \Sigma \mathrm{J}_p^m \frac{\mathrm{I}}{w_p} R_p^m \sin w_p, \end{aligned} \tag{5}$$

where m denotes the number of accents to be attached to j and J.

Next by successive direct differentiation

$$v^s \frac{d^s R}{dv^s} = \Sigma \frac{\Gamma(\mathrm{I})}{\Gamma(\mathrm{I}-s)} R \cos w, \qquad \frac{d^s R}{dV^s} = \Sigma i^s \{\cos s\tfrac{\pi}{2} . R \cos w - \sin s\tfrac{\pi}{2} . R \sin w\}. \tag{6}$$

Put

$$\mathrm{D}_v = [v^{-1}\delta v]\, v \frac{d}{dv}, \qquad \mathrm{D}_V = \delta V \frac{d}{dV},$$

then a known form of expansion gives the expression

$$\mathrm{R} = R + \delta R = \{\epsilon^{\Sigma(\mathrm{D}_v + \mathrm{D}_V)}\} R$$

$$= \{\Sigma (\mathrm{I} + \mathrm{D}_v + \frac{\mathrm{I}}{\underline{2}} [\mathrm{D}_v]^2 + \dots)(\mathrm{I} + \mathrm{D}_V + \frac{\mathrm{I}}{\underline{2}} [\mathrm{D}_V]^2 + \dots) \dots \} R. \tag{7}$$

From the value assigned to D the following expressions can be derived:—

$$[\mathrm{D}_v]^n R \cos w = \left(\frac{\mathrm{I}}{2}\right)^n \{\mathrm{I}(\mathrm{I}-\mathrm{I}) \dots (\mathrm{I}-n+\mathrm{I})\} [c_1 + c_2 + c_3 + \dots + c_n]^n \cos (w + q'\gamma_1 + q''\gamma_2 + \dots + q^n\gamma_n),$$

$$[\mathrm{D}_V]^n R \cos w = \left(\frac{\mathrm{I}}{2}\right)^n \{q'q'' \dots q^n\} (i)^n \quad [\mathrm{C}_1 + \mathrm{C}_2 + \mathrm{C}_3 + \dots + \mathrm{C}_n]^n \cos (w + q'\gamma_1 + q''\gamma_2 + \dots + q^n\gamma_n), \tag{8}$$

$$[\mathrm{D}_v]^m [\mathrm{D}_V]^{m-n} R \cos w = \left(\frac{\mathrm{I}}{2}\right)^n \{q^m q^{m+1} \dots q^n\} (i)^{n-m} \{\mathrm{I}(\mathrm{I}-\mathrm{I}) \dots (\mathrm{I}-m+\mathrm{I})\} [c_1 + c_2 + \dots + c_n]^m [\mathrm{C}_m + \mathrm{C}_{m+1} + \dots + \mathrm{C}_n]^{n-m} \cos (w + q'\gamma_1 + q''\gamma_2 + \dots + q^n\gamma_n).$$

Then putting for brevity

$$\begin{aligned} (\mathrm{I}c)^m &= \{\mathrm{I}(\mathrm{I}-\mathrm{I}) \dots (\mathrm{I}-m+\mathrm{I})\} [c_1 + c_2 + \dots + c_m]^m, \\ (q^i\mathrm{C})^m &= (i)^m \{q'q'' \dots q^m\} \quad [\mathrm{C}_1 + \mathrm{C}_2 + \dots + \mathrm{C}_m]^m, \end{aligned} \tag{9}$$

the complete value of the general term of R will be

$$\mathrm{R}\cos \mathrm{w} = R\cos w + \frac{\mathrm{I}}{2} R\,(\mathrm{Ic}_1 + q'i\mathrm{C}_1)\cos(w + q'\gamma_1) + \ldots$$

$$+ \frac{\mathrm{I}}{\lfloor n} \left(\frac{\mathrm{I}}{2}\right)^n R\,(\mathrm{Ic} + qi\mathrm{C})^n \cos(w + \Sigma_1^n q^m \gamma_m) + \ldots \quad (10)$$

In the preceding expressions the coefficients $q'\ q''\ \ldots\ q^m$ only take the values plus or minus unity, and have been introduced for the purpose of clearly showing the changes of sign produced by changes of sign in the argument.

Let

$$\mathrm{R} = \Sigma\{R_p + \mathrm{A}_p\}\cos w_p, \quad (11)$$

where A_p denotes the sum of the coefficients of the argument w_p which arises from the portion of R depending on the perturbations, so that $R_p + \mathrm{A}_p$ denotes the complete value of the coefficient of the argument w_p in the value of R. The function A is therefore a constant, and a function of R_p, the coefficients I, i, q, and the indeterminate coefficients c and C.

Let (R) be a function of similar form to R, and such that

$$(\mathrm{R}) = \mathrm{x}^{(\mathrm{F})}\mathrm{y}^{(\mathrm{G})}\mathrm{z}^{(\mathrm{H})}\,\mathrm{R}, \quad (12)$$

so that the general term of (R) may be written in the form

$$(\mathrm{R})\cos \mathrm{w} = (\Lambda)\,\mathrm{x}^{\mathrm{F}+(\mathrm{F})}\mathrm{y}^{\mathrm{G}+(\mathrm{G})}\mathrm{z}^{\mathrm{H}+(\mathrm{H})}\cos\{(\lambda) + f\mathrm{X} + g\mathrm{Y} + h\mathrm{Z}\}, \quad (13)$$

and is evidently merely a particular case of the general term (1). Its expansion will be identical in form with that of (10). Suppose therefore,

$$(\mathrm{R}) = \Sigma x^{(\mathrm{F})} y^{(\mathrm{G})} z^{(\mathrm{H})}\{R_p + (\mathrm{A})_p\}\cos w_p, \quad (14)$$

where $(\mathrm{A})_p$ only differs from A_p in F, G, H being replaced by F+(F), G+(G), H+(H) respectively; so that $(\mathrm{A})_p$ is merely a particular case of A_p.

Suppose the coefficients of the perturbations in the six elements of the orbit to be represented by the $6k$ indeterminate coefficients $c_1 \ldots c_{6k}$, then the function A_p can be written in the form

$$\mathrm{A}_p = \Sigma\phi(r)\,c_s + \Sigma\phi'(r)\,(c_s c_{s_1}) + \Sigma\phi''(r)\,(c_s c_{s_1} c_{s_2}) + \ldots + \Sigma\phi^n(r)\,(c_s \ldots c_{s_n}) + \ldots, \quad (15)$$

where $\phi(r), \ldots \phi^n(r)$ are known constants, functions of R_r, I_r, i_r, and $c_s, \ldots c_{s_n}$ are particular cases of the series of indeterminate coefficients which represent the perturbations of the elements. The summation extends to all the combinations of the suffixes r and $s, \ldots s_n$ which will yield a term with the argument w_p.

By means of (10) the value of the coefficient A_p as developed in (15) can be written down to the nth order. It is merely

necessary to know the different combinations of the arguments $w_r, \gamma_1, \ldots \gamma_k$ which will render $w_r + q\gamma_1 + \ldots + q^m\gamma_m$ equal to the value w_p. Suppose there are l such independent combinations of $w_r, \gamma_1, \ldots \gamma_k$, then by giving to $s, \ldots s_m$ and r these l series of values, the complete value of $\Sigma\phi^m(r)\,(c_s \ldots c_{s_m})$ as it exists in A_p will be obtained. It only remains therefore to determine these l combinations of the arguments. For this purpose let

$$R = \Sigma_0^k R_m \cos w_m.$$

By direct successive multiplication form the functions

$$\{R\}^2,\ \{R\}^3, \ldots \{R\}^n,$$

neglecting terms of a higher order than necessary for an approximation to the given order. Then the different combinations of m in the value of the coefficient of the argument w_p in the function $\{R\}^m$ will be the l combinations of $r, s_1, \ldots s_n$ in the value of $\Sigma\phi^m(r)\,(c_s \ldots c_{s_m})$ as it exists in the coefficient A_p.

In this way the value of A_p can be completely determined to the nth order, or the $2n$th order as usually computed, so that R may be regarded as completely determined to that order.

Suppose the system of elements represented by v, V to be a canonical system, so that the differential equations which give the perturbations in the elements may be written in the form

$$\frac{dv}{dt} = \frac{dR}{dV} = -\Sigma iR \sin w, \qquad \frac{dV}{dt} = \frac{dR}{dv} = v^{-1}\Sigma IR \cos w. \quad (16)$$

Let it be assumed that

$$\int \begin{matrix}\cos\\ \sin\end{matrix}(w)\,dt = \pm\frac{I}{w}\begin{matrix}\sin\\ \cos\end{matrix}(w),$$

and integrate the system of equations (16). They become

$$v^{-1}\delta v = \Sigma\frac{i}{v}\frac{I}{w}\{R + \delta R\}\cos w, \qquad \delta V = \Sigma\frac{I}{v}\frac{I}{w}\{R + (\delta R)\sin w\}. \quad (17)$$

Therefore

$$\begin{aligned} c_p \cos w_p &= \{i_p\frac{I}{v}\frac{I}{w_p}R_p + i_r\frac{I}{v}\frac{I}{w_p}A_p\}\cos w_p, \\ C_p \sin w_p &= \{I_p\frac{I}{v}\frac{I}{w_p}R_p + I_r\frac{I}{v}\frac{I}{w_p}(A)_p\}\sin w_p. \end{aligned} \quad (18)$$

In this manner, amongst the $6k$ coefficients $c_1, \ldots c_{6k}$, there will be obtained $6k$ independent equations of the form

$$c_p = \frac{I}{v}\frac{I}{w_p}\{i_pR_p + \Sigma i_r\phi'(r)\,c_s + \ldots + \Sigma i_r\phi^n(r)\,(c_s \ldots c_{s_n}) + \ldots\}, \quad (19)$$

where, for brevity, I is included under i and C under c.

This system of $6k$ equations amongst the $6k$ indeterminate coefficients can be completely solved without difficulty and the values of the $6k$ coefficients $c_1, \ldots c_{6k}$ can be determined to any required order.

It would not be difficult to transform the preceding equations into others of a still more advantageous form, but this is unnecessary at present. In practice it would be found essential to have seven series of unknown coefficients, the extra one being required for the perturbations of the mean motion. Therefore, although the preceding system of equations is very simple, and can be written down without difficulty to any required order, it still retains the serious disadvantage of requiring seven variables. When indeterminate coefficients are employed, this multiplicity of variables is the great difficulty of the method of perturbed elements, for it involves the solution of a system of $7k$ equations amongst $7k$ unknown quantities, whereas, when the coordinates are made the direct variables, as in my "General Method of Treating the Lunar Theory," it is only necessary to solve a system of $3k$ equations amongst $3k$ unknown quantities, and this requires far less labour. Moreover, the preceding method requires the entire system of perturbations to be attacked at once, and it is not practicable to determine the value of any one coefficient by itself. It remains therefore to remove these disadvantages by further developing the method.

Instead of supposing R to be developed in terms of the variables represented by δv and δV, let it be developed in terms of the n times as many variables represented by $\delta_1 v, \ldots \delta_n v$ and $\delta_1 V, \ldots \delta_n V$, and denoted generally by $\delta_m v$ and $\delta_m V$. As the functions represented by $\delta_m v$ and $\delta_m V$ are perfectly analogous to those represented by δv and δV, the form of the expansion will not be altered, and it will merely be necessary to make some slight changes in the notation. Put, then,

$$\left[R_s^m (\mathrm{I}_r j_s^m) \frac{\mathrm{I}}{w_s}\right]^k = \{\mathrm{I}_r (\mathrm{I}_r - 1) \ldots (\mathrm{I}_r - k + 1)\} \left(j_{s_1}^m R_{s_1}^m \frac{\mathrm{I}}{w_{s_1}} + \ldots + j_{s_k}^m R_{s_k}^m \frac{\mathrm{I}}{w_{s_k}}\right)^k \tag{20}$$

$$\left[R_s^m (q i_r \mathrm{J}_s^m) \frac{\mathrm{I}}{w_s}\right]^k = \{q' q'' \ldots q^k\} (i)^k \left(\mathrm{J}_{s_1}^m R_{s_1}^m \frac{\mathrm{I}}{w_{s_1}} + \ldots + \mathrm{J}_{s_k}^m R_{s_k}^m \frac{\mathrm{I}}{w_{s_k}}\right)^k$$

and let Σ denote a summation with respect to m, so that, for example,

$$\left[\Sigma R_s^m (\mathrm{I}_r j_s^m) \frac{\mathrm{I}}{w_s}\right]^k = \{\mathrm{I}_r (\mathrm{I}_r - 1) \ldots (\mathrm{I}_r - k + 1)\}$$

$$\left([j'_{s_1} R'_{s_1} + \ldots + j_{s_1}^n R_{s_1}^n] \frac{\mathrm{I}}{w_{s_1}} \ldots + [j'_{s_k} R'_{s_k} + \ldots + j_{s_k}^n R_{s_k}^n] \frac{\mathrm{I}}{w_{s_k}}\right)^k \tag{21}$$

Then the general term of R can be written in the form

$$\mathrm{R}\cos\mathrm{w} = R_r\cos w_r + \frac{1}{2}\left[\Sigma R^m_{s_1}(\mathrm{I}_r j^m_{s_1} + q' i_r \mathrm{J}^m_{s_1})\frac{1}{w_{s_1}}\right] R_r\cos(w_r + q' w_{s_1}) + \ldots$$

$$+ \frac{1}{\underline{n}}\left(\frac{1}{2}\right)^n\left[\Sigma R^m_s(\mathrm{I}_r j^m_s + q i_r \mathrm{J}^m_s)\frac{1}{w_s}\right]^n R_r\cos(w_r + \Sigma^n_1 q w_s) + \ldots \qquad (22)$$

Substitute this value with that of (R) in the differential equations, and on integration they become

$$v^{-1}\delta v = \frac{1}{v} i_r \frac{1}{w_r} R_r\cos w_r + \ldots + \frac{1}{v} i_r \frac{1}{w_r + \Sigma^n_1 q w_s} \times$$

$$\frac{1}{\underline{n}}\left(\frac{1}{2}\right)^n\left[\Sigma R^m_s(\mathrm{I}_r j^m_s + q i_r \mathrm{J}^m_s)\right.\qquad\left.\frac{1}{w_s}\right]^n R_r\cos(w_r + \Sigma^n_1 q w_s) + \ldots \qquad (23)$$

$$\delta V = \frac{1}{v}\mathrm{I}_r\frac{1}{w_r} R_r\sin w_r + \ldots + \frac{1}{v}\mathrm{I}_r\frac{1}{w_r + \Sigma^n_1 q w_s} \times$$

$$\frac{1}{\underline{n}}\left(\frac{1}{2}\right)^n\left[\Sigma R^m_s(\mathrm{I}_r j^m_s + q i_r \mathrm{J}^m_s + (\mathrm{I})\, j^m_s)\frac{1}{w_s}\right]^n R_r\sin(w_r + \Sigma^n_1 q w_s) + \ldots$$

where, as before, the transformation of R into (R) is effected by the addition of the quantity (I), where (I) is an absolutely constant quantity, which is the same for all values of r and s.

Assume that the perturbations of the elements of the order of the mth power of the disturbing forces are represented by the expressions

$$v^{-1}\delta_m v = j^m\frac{1}{w} R^m\cos w, \qquad \delta_m V = \mathrm{J}^m\frac{1}{w} R^m\sin w, \qquad (24)$$

then it only remains to determine the value of the coefficients $j' \ldots j^n$ and $\mathrm{J}' \ldots \mathrm{J}^n$ and the quantities $R' \ldots R^n$, and the right hand side of the equations (23) will become an explicit function of known quantities, so that the complete value of the perturbations of the elements will have been determined to the nth order of the disturbing forces.

Neglecting the square of the disturbing forces, the equations (22) can be written in the form

$$v^{-1}\delta_1 v = \frac{1}{v} i_p \frac{1}{w_p} R_p\cos w_p, \qquad \delta_1 V = \frac{1}{v}\mathrm{I}_p\frac{1}{w_p} R_p\sin w_p, \qquad (25)$$

where the suffix r has been replaced by p. Comparing with (24),

$$j'_p = \frac{1}{v} i_p, \qquad \mathrm{J}'_p = \frac{1}{v}\mathrm{I}_p, \qquad R'_p = R_p. \qquad (26)$$

Thus all the terms depending on j', J', R' may be regarded as known.

As far as these terms are concerned, the complete value of the term in the disturbing function which has the argument w_k may be written in the form

$$\mathrm{R}\cos \mathrm{w} = R_k \cos w_k + \left[\frac{1}{2} R_{s_1} (\mathrm{I}_r i_{s_1} + q' i_r \mathrm{I}_{s_1}) \frac{1}{v} \frac{1}{w_{s_1}}\right] R_r \cos (w_r + q' w_{s_1}) + \ldots$$

$$+ \frac{1}{\underline{|n}} \left[\frac{1}{2} R_s (\mathrm{I}_r i_s + q i_r \mathrm{J}_s) \frac{1}{v} \frac{1}{w_s}\right]^n R_r \cos (w_r + \Sigma_1^n q w_s) + \ldots \quad (27)$$

with the single condition that the suffixes r, s_1, s_2, $\ldots$ s_n which have been used to distinguish quantities belonging to different arguments are to be given in turn all the different combinations of values which will make $w_r + q' w_{s_1} + \ldots + q^n w_{s_n}$ equal to w_k. These values will be identical with the l different combinations of the suffixes m in the value of the coefficient of the term with the argument w_k in the function $\{R\}^n$ or nth power of R.

The coefficients $j'', \ldots j^n$ and $\mathrm{J}'', \ldots \mathrm{J}^n$ can be determined in exactly the same manner, and will give rise to similar expression, the principal difference being that the simple coefficients i_s, I_s will be replaced by more complex functions. For the present it is unnecessary to write down these terms seriatim, although it can be at once done from equations (23). The general expression for the terms of the perturbations of the elements of the nth order of the disturbing forces will be

$$v^{-1} \delta_n v = \Sigma j'_r \frac{1}{w_p} R_r \frac{1}{\underline{|b_1} \ldots \underline{|b_m}}$$

$$\left\{\left[\frac{1}{2} R_s (\mathrm{I}_r j'_s + q i_r \mathrm{J}'_s) \frac{1}{w_s}\right]^{b_1} \ldots \left[\frac{1}{2} R_s (\mathrm{I}_r j_s^m + q i_r \mathrm{J}_s^m) \frac{1}{w_s}\right]^{b_m}\right\} \cos (w_r + \Sigma_1^b q w_s)$$

$$\delta_n V = \Sigma \mathrm{J}'_r \frac{1}{w_p} R_r \frac{1}{\underline{|b_1} \ldots \underline{|b_m}} \quad (28)$$

$$\left\{\left[\frac{1}{2} R_s (\mathrm{I}_r j'_s + q i_r \mathrm{J}_s + [\mathrm{I}] j'_s) \frac{1}{w_s}\right]^{b_1} \ldots \left[\frac{1}{2} R_s (\mathrm{I}_r j_s^m + q i_r \mathrm{J}_s^m + [\mathrm{I}] j_s^m) \frac{1}{w_s}\right]^{b_m}\right\} \sin (w_r + \Sigma_1^b q w_s),$$

with the conditions that the constants are to take in succession all values which satisfy the equations

$$\begin{aligned} w_r + q' w_{s_1} + q'' w_{s_2} + \ldots + q^b w_{s_b} &= w_p \\ b_1 + b_2 + b_3 + \ldots + b_m &= b \\ b_1 + 2b_2 + 3b_3 + \ldots + m b_m &= n - 1. \end{aligned} \quad (29)$$

These expressions may seem to be complicated, but this is inseparable from the terms being given for the nth order of the dis-

turbing forces. As far as the fifth power of the disturbing forces or m^{11} of the ordinary notation, they may be written down in an extremely simple form, and even to the tenth order, or m^{21}, they are neither complicated nor lengthy. The different combinations which can be taken by the suffixes $r, s_1, \ldots s_n$ will be identical with the combinations of the suffixes m in the value of the coefficient of the term with the argument w_p, in the function $\{R\}^b$ or bth power of R.

In this manner, therefore, the complete value of the perturbations of the elements of the orbit may be determined to the nth order of the disturbing forces, and this forms a complete solution of the problem of disturbed elliptic motion. The expressions which have been obtained for the perturbations admit of being transformed into still more advantageous forms. It is necessary, however, to defer these extensions and developments to a place in a second and more elaborate communication. It may be mentioned, however, that by these transformations the complete value of the perturbations of the elements may be made to assume the following form:—

$$v^{-1}\delta v = \left([\mathrm{P}]^p_1 R_p + \{[\mathrm{P}]^r_1 [\mathrm{P}']^r_{s_1}\} R_r R_{s_1} + \ldots \right.$$
$$\left. + \{[\mathrm{P}]^r_1 ([\mathrm{P}^n]^r_{s_1} + \ldots + [\mathrm{P}^n]^r_{s_n})^n\} (R_r R_{s_1} \ldots R_{s_n}) + \ldots \right) \cos w_p$$

$$\delta V = \left([\mathrm{Q}]^p_1 R_p + \{[\mathrm{Q}]^p_1 [\mathrm{Q}']^r_{s_1}\} R_r R_{s_1} + \ldots \right. \qquad (30)$$
$$\left. + \{[\mathrm{Q}]^r_1 ([\mathrm{Q}']^r_{s_1} + \ldots + [\mathrm{Q}^n]^r_{s_n})^n\} (R_r R_{s_1} \ldots R_{s_n}) + \ldots \right) \sin w_p.$$

In this expression $R_p, R_r, R_{s_1}, \ldots R_{s_n}$ are the coefficients of the arguments $w_p, w_r, w_{s_1} \ldots w_{s_n}$ in the ordinary disturbing function. The functions denoted by $[\mathrm{P}]^r_{s_m}$ and $[\mathrm{Q}]^r_{s_m}$ are known functions of the coefficients $\mathrm{I}_r, \mathrm{I}_{s_m}, i_r, i_{s_m} \ldots$ and the integrating factors $w_{s_m} \ldots$ They may be transformed into explicit functions of the form

$$\phi\left\{(\mathrm{I}_r i_{s_m} + q i_r \mathrm{I}_{s_m} \quad) \frac{\mathrm{I}}{v} \frac{\mathrm{I}}{w_{s_m}}\right\} = [\mathrm{P}]^r_{s_m}$$

$$\psi\left\{(\mathrm{I}_r i_{s_m} + q i_r \mathrm{I}_{s_m} + (\mathrm{I})\, i_{s_m}) \frac{\mathrm{I}}{v} \frac{\mathrm{I}}{w_{s_m}}\right\} = [\mathrm{Q}]^r_{s_m},$$

only under this form the terms depending on high powers of the disturbing forces are rendered more complex and lengthy.

No restriction has been placed on the number of variables represented by v and V. In the expression for the general term of R it has been assumed that they will be only six in number, or x, y, z, X, Y, Z. These are the number required by the lunar theory. The method can be applied without alteration to the planetary theory, when there will be twelve variables,

$x, x', y, y', z, z', X, X', Y, Y', Z, Z'$, the accented quantities referring to the disturbing planet. It can be applied, however, to any number of such variables, and absolutely without alteration.

In the preceding investigation, instead of employing the ordinary elliptic elements, use has been made of the six undefined elements whose mean values are x, y, z, X, Y, Z, and no restriction has been placed on them beyond the single condition that they are to be such as will yield a canonical system of differential equations. The perturbations of these elements have been completely determined in explicit series of functions of the form

$$R_r = (A)x^{F_r}y^{G_r}z^{H},$$

$$w_s = (\lambda) + f_sX + g_sY + h_sZ, \tag{31}$$

$$(I_ri_s + qi_rI_s)\frac{I}{v} = (F_rf_s + qF_sf_r)\frac{I}{x} + (G_rg_s + qG_sg_r)\frac{I}{y} + (H_rh_s + qH_sh_r)\frac{I}{z}.$$

The value of the disturbing function has been already determined by me to the ninth order in terms of the usual elements of the elliptic orbit. Two courses can be adopted to render this result available for the purpose of the present method; either it can be transformed into an expression in terms of the six elements, x, y, z, X, Y, Z, or, *vice versâ*, the expression (31) can be transformed into terms of the usual elements.

Suppose

$$X + Y + Z = L + A + B + \text{constant} = w_r,$$

where L, A, B denote the mean longitude of the Moon and the position of the perigee and ascending node of the lunar orbit. Then, as long as this condition is maintained, the arguments of the terms in the disturbing function will remain unaltered, with the exception that the coefficients f_r, g_r, h_r will be transformed into other particular values f_k, g_k, h_k.

Similarly the coefficient of the term with the argument w_r in the ordinary disturbing function may be written in the form

$$b_1a^{F_k}e^{G_k}\eta^{H_k}(1 + b_2a^2 + b_3e^2 + b_4\eta^2 + \ldots),$$

where F_k, G_k, H_k are numerical constants, and assuming

$$x = \phi_1(a, e, \eta), \qquad y = \phi_2(a, e, \eta), \qquad z = \phi_3(a, e, \eta),$$

the preceding may be transformed into the value

$$c_1x^{F_r}y^{G_r}z^{H_r}(1 + c_2x^2 + c_3y^2 + c_4z^2 + \ldots);$$

the only difference being that F_r, G_r, H_r will be different integers to F_k, G_k, H_k.

It is evident, therefore, that by properly defining x, y, z, either the usual disturbing function can be transformed into

explicit functions of X, Y, Z, x, y, z, or the equations (31) transformed into explicit functions a, e, η, L, A, B, and their coefficients of F_k, G_k, H_k, f_k, g_k, h_k.

It may be remarked that the preceding method has been already employed to deduce some remarkably interesting and important theorems with regard to the terms of long period in the mean longitude. From their form it is obvious that any single term or set of terms can be determined by themselves, so that the method is peculiarly well adapted for determining the terms of long period which converge slowly and require the fourth and fifth powers of the disturbing forces to be taken into consideration. In a subsequent communication I hope to be able to deduce by its aid some important theorems with regard to the secular inequalities in the motion of the planets depending on the third and fifth powers of the disturbing forces.

London,
December 9, 1878.

Note on the Presence of Particles of Meteoric Dust in the Atmosphere.

By A. C. Ranyard, Esq.

In a Paper* read before the British Association in 1852, Professor Andrews announced that he had discovered particles of native iron in the basalt of the Giant's Causeway. Having reduced portions of the rock in a porcelain mortar to a tolerably fine powder, magnetic particles were collected by passing a magnet several times through the powder. The particles adhering to the magnet were then placed under the microscope and moistened with an acid solution of sulphate of copper. On some of them copper was deposited in a manner which indicated the presence of native iron. Professor Andrews appears to have suggested that the particles of native iron may have been derived from meteors which fell when the basalt was in a plastic condition.

In 1867 Dr. T. L. Phipson published a book entitled *Meteors, Aerolites, and Falling Stars*, in which he states† that he had frequently exposed to the wind a sheet of glass covered with some transparent mucilaginous substance in order to catch the particles of dust floating in the air. He says: "I have found that when a glass covered with pure glycerine is exposed to a strong wind late in November, it receives a certain number of *black angular particles*, some three or four of which may be thus collected in the space of a couple of hours. The experiment being made far in the country, away from the 'smuts' of a town, the black particles show themselves all the same. They are, however, not soot or charcoal; they can be dissolved in strong

* *Brit. Assoc. Reports* for 1852. Part II. pp. 34, 35. † *See* pp. 229, 230.

hydrochloric acid, and produce yellow chloride of *iron* upon the glass plate." He continues: "Although I have made this experiment at various periods of the year, and in different countries, it is only in the winter months that the black particles, giving with hydrochloric acid chloride of *iron*, have been met with."

Towards the end of 1871 Dr. Nordenskjöld collected some apparently pure snow which fell in the neighbourhood of Stockholm during a heavy snowstorm.* On melting a cubic metre of the snow collected, towards the end of the fall, he found that it left a black résidue, from which he was able to extract with a magnet particles which, when rubbed in an agate mortar, exhibited metallic characters, and on being treated with acid proved to be iron.

In 1872 Dr. Nordenskjöld obtained some snow from off the ice of the Rantajerwi, at a spot which is separated by a dense forest from the nearest houses at Evoia, in Finland. When melted the snow yielded a soot-like residue, which under the microscope was found to consist of white or yellowish white granules, with a black carbonaceous substance, from which the magnet removed black grains, which when rubbed in a mortar were seen to be iron.

The Arctic Expedition of 1872 presented an opportunity for the collection of snow in a region removed as far as possible from human habitations. On August 8 the snow covering the drift ice, at lat. 80° N. and long. 13° E., was observed to be thickly covered with small black particles, while in places these penetrated to a depth of some inches the granular mass of ice into which the underlying snow had been converted. Magnetic particles were abundant, and their power to reduce copper sulphate was established. Again, on September 2, in lat. 80° N., long. 15° E., the ice-field was found covered with a bed of freshly fallen snow 50 mm. thick, then a more compact bed 8 mm. in thickness, and below this a layer 30 mm. thick of snow converted into a crystalline granular mass. The latter was full of black granules, which became grey when dried, and exhibited the magnetic and chemical characters already referred to; they amounted to 0·1 to 1·0 millegramme in a cubic metre of snow. Analysis of some millegrammes enabled Dr. Nordenskjöld to establish the presence of iron, phosphorus, cobalt, and probably nickel.

During the years 1874, 1875, and 1876 M. Tissandier published in the *Comptes Rendus*,† an interesting series of papers on his examination of atmospheric dust. He showed that in the dust deposited upon the towers of the Church of Notre Dame, as well as in the solid matter deposited from rain-water, there were metallic particles containing iron, nickel, and cobalt. On examining these particles under the microscope, he found that they were very similar in appearance to particles which he was

* *See Comptes Rendus*, lxxvii., 463.

† *See* the Numbers for March 28, 1874; January 4, 1875; October 4, 1875; and July 3, 1876.

able to detach by friction from the surface of meteorites, and he concludes that they are the solidified metallic rain detached from meteoric masses during their passage through the atmosphere.

Dr. Walter Flight published, in the *Geological Magazine* for March and April 1875, an important paper upon meteoric dust, which has since been reprinted in the *Arctic Manual*. After referring to Dr. Nordenskjöld's observations, he remarks that the dust from the polar ice north of Spitzbergen bears a great resemblance to a substance termed *cryoconite* "which was found in Greenland in 1870 very evenly distributed, in not inconsiderable quantity, on shore ice, as well as on ice thirty miles from the coast and at a height of 700 metres above the sea. The dust of both localities has probably a common origin. The cryoconite is chiefly met with in the holes of the ice, forming a layer of grey powder at the bottom of the water filling the holes. Considerable quantities of this substance are often carried down by streams which traverse the glacier in all directions. The ice hills which feed these streams lie towards the east, on a slowly rising, undulating plateau, on the surface of which not the slightest trace of stone or larger rock masses was observed. The actual position of this material, to which Dr. Nordenskjöld has given the name of cryoconite (κρύος ice, and κόνις dust), in open hollows on the surface of the glacier, precluded the possibility of its having been derived from the ground beneath."

After describing the chemical composition of cryoconite, Dr. Flight continues: "The origin of cryoconite is highly enigmatical. That it is not a product of the weathering of the gneiss of the coast is shown by its inferior hardness, indicating the absence of quartz, the large proportion of soda, and the fact of mica not being present. That it is not dust derived from the basalt area of Greenland is indicated by the subordinate position iron-oxide occupies among the constituents, as well as by the large proportion of silicic acid. We have then to fall back on the assumption that it is either of volcanic or cosmical origin." . . . . "The cryoconite, whencesoever it comes, contains one constituent of cosmical origin. Dr. Nordenskjöld extracted, by means of the magnet, from a large quantity of material sufficient particles to determine their metallic nature and composition. These grains separate copper from a solution of the sulphate and exhibit conclusive indications of the presence of cobalt (not only before the blowpipe, but with solution of potassium-nitrite), of copper, and of nickel, though in the latter case with a smaller degree of certainty, through the reactions of this metal being of a less delicate character."

In 1876 Mr. John Murray published a paper in the *Proceedings of the Royal Society of Edinburgh*,* in which he gave an account of his examination of the deposits found at the bottom of the oceans and seas visited by H.M.S. *Challenger*. In many of

* Vol ix., pp. 247-262.

the deep sea clays Mr. Murray found numerous magnetic particles, some of which he extracted by means of a magnet carefully covered with paper. On placing them under a microscope and moistening with the acid solution of sulphate of copper, he found that copper was deposited on some of the particles. From this and the circumstance that the particles bore a strong resemblance to particles found on the "mammillated outer surface of the Cape Meteorite," Mr. Murray concluded that the particles had a cosmic origin.

He suggests that the reason meteoric particles are found in such abundance in the deep sea clays is that at the bottom of the ocean far from land such particles would not be washed away or so rapidly covered up as in the case of deposits formed nearer to continents, and they would consequently appear to form a larger proportion of the deposited matter. He also suggests that the nickel present in meteoric iron would greatly retard the oxidation of such particles. Professor Alexander Herschel has, I understand, examined under the microscope some of the particles extracted by Mr. Murray, and concurs with him in the opinion that they probably have a cosmic origin.

In September 1876 Mons. E. Yung published a paper* entitled "Étude sur les Poussières cosmiques." He gives a plate showing iron particles which he had found in snow that fell at the Hospice of St. Bernard. During the years 1875 and 1876 he examined snow which fell on several other Swiss mountains, and in every instance found iron particles. He also extracted, by means of a magnet, globules of iron from dust collected upon the towers of churches. The iron particles which he figures in his plate are mostly spherical or tear-shaped, with projecting points and threads of metal. His observations entirely confirm those of M. Tissandier.

The above observations seem to point to a conclusion which has, I believe, been advocated for some time past by Mr. Proctor, viz. that meteoric matter is continually falling in quantities which, in the lapse of ages, must accumulate so as materially to contribute to the matter of the Earth's crust.† There can be little doubt that in the course of a year millions of meteors enter the Earth's atmosphere. A few of the larger masses reach the

* See *Bulletin de la Société Vaudoise des Sciences Naturelles*. Vol. xiv., pp. 494-506.

† The iron particles probably only form a very small part of the meteoric dust continually falling—for, of the larger masses which have been seen to fall, it has been estimated that not one in fifty is iron. Dr. Flight informs me that in the British Museum there are 202 stony meteorites, all of which have been seen to fall, and that there are only four iron meteorites which have been seen to fall. Stony meteorites consist for the most part of olivine, augite, hornblende, felspar, and other minerals, most of which are common in volcanic and metamorphic rocks, which therefore cannot be distinguished as having a meteoric origin unless they are found in masses. It is worthy of remark that all the elements which are common in meteorites are also common in the stratified rocks.

Earth's surface, but by far the greater number appear to be consumed in the higher atmosphere. The above observations show that minute particles of iron frequently reach the Earth's surface without having undergone any change such as might be expected to result from their passage through the air in an incandescent state. The subject is one of considerable interest, and I therefore give an account of a somewhat incomplete experiment which I made while crossing the Atlantic at the beginning of last September. When at a distance of about 1,000 miles from the American coast, I exposed some glass plates covered with glycerine to the wind. They were placed upon a wind vane behind a tin funnel which directed a current of air upon the centre of the plate. The wind vane was mounted near to the prow of the vessel, and during the time of the exposure the wind was blowing nearly at right angles to the course of the vessel.

Four plates were exposed for periods of 30 hours, 24 hours, 18 hours, and 20 hours respectively. Immediately after the exposure the plates were placed in a box such as is ordinarily used by photographers for carrying negatives, and the whole was wrapped in paper so as carefully to exclude dust till the plates could be brought to England for examination. When the box was again opened the plates were placed under the microscope, and, at Mr. Neison's suggestion, I treated them first with dilute hydrochloric acid and then with sulphocyanide of potassium, a process which would indicate the presence of iron particles by a bright red stain.

On the plate which was exposed for 18 hours a rather large particle containing iron was found. It was of a dark brown colour and was somewhat elongated, tapering slightly towards one end, but was not angular like the particles caught by Dr. Phipson. It was clearly visible to the naked eye, and I estimated it to be between the $\frac{1}{100}$ and the $\frac{1}{150}$ of an inch in its longest diameter. There were other traces of iron upon the plates, but only in very minute quantities, always in connection with minute hairs and cells which had lodged in the glycerine. I do not feel satisfied with the experiment; for although the plates were carefully cleaned and the glycerine made use of showed no traces of iron, the box in which the plates were carried had been lying about in Professor Henry Draper's laboratory in New York, and I omitted to make sure that it was perfectly free from dust before making use of it. On another occasion I would recommend that the box in which the plates are to be carried should be carefully cleaned and coated on the inside with glycerine. A box without a lock and with brass hinges should be made use of. It might also be worth while to vary the experiment by exposing a magnet to the wind with the poles covered with tinfoil. On removing the tinfoil the magnetic particles should be allowed to fall on a plate covered with glycerine, which could be kept for examination.

There can be little doubt that the air up to a great height above the Earth's surface is impregnated with dust. The sky as seen from the highest mountains appears of a dark blue, which indicates the presence of particles small compared with the wave length of light. It has usually been assumed that these particles must have been carried upwards from the Earth's surface by convection currents, but Professor Tyndall's experiments in Switzerland tend to show that the higher air is comparatively free from germs. I would suggest that the blue colour may be caused by dust derived from the débris of meteors, the smaller particles of which may possibly occupy months or even years in falling to the Earth's surface.

Much evidence has been collected by Professor von Niessl and others which tends to show that many of the larger meteoric masses enter the Earth's atmosphere with velocities which indicate that they are moving in hyperbolic orbits, and consequently do not belong to the solar system. It seems therefore probable that at all events a certain proportion of the meteoric dust is derived from sources outside the solar system. The Earth and planets, as they are carried along with the Sun in his motion through space, would thus receive a larger proportion of meteoric matter on their northern than on their southern hemispheres, and I would suggest, as a theory worthy of consideration, that this may account for the preponderating mass of the continents in the northern hemisphere of the Earth, and for the fact, which has so frequently been pointed out by physical geographers, that the great terrestrial peninsulas all taper towards the Southern Pole.*

The experiments of Professor Arthur Wright, of Yale, show that when meteoric masses are heated, considerable amounts of occluded gas are given off. We shall therefore, in considering the results which must follow from the continuous fall of meteoric matter, have to take into account the fact that gaseous matter is probably continually being added to the atmosphere. If the amount of gaseous matter taken from the air and stored up in a solid form by the agency of plants and animals, and by the oxi-

* The following facts with regard to the Moon and the planet *Mars* may also have some connection with the unequal addition of foreign matter on their northern and southern hemispheres. On the Moon the volcanic action has been decidedly more intense in the southern than in the northern hemisphere, and it will also be noticed that the great crater ranges run mostly north and south. On the planet *Mars*—if we adopt the delineation of the seas and continents given by Proctor in his map, which was chiefly made from the drawings of the planet by Dawes—there is, as on our Earth, a greater proportion of ocean surface in the southern than in the northern hemisphere. On *Mars* the land surface is decidedly greater than the ocean surface, so that the seas appear reduced to mere lakes and narrow inlets; but it will be noticed that these have their broadest expansion in the southern hemisphere, and that what has been termed the equatoreal girdle of continents has its medial line decidedly to the north of the Martial equator.

dation of mineral substances, does not counterbalance the amount continually being added to the atmosphere from meteors, together with the supplies derived from volcanic vents and from other sources from which the atmosphere may be recruited, it will be evident that the total amount of the atmosphere must either be increasing or decreasing. And the point to which I wish to draw attention is that such an increase or decrease would in time serve to account for great changes of temperature at the Earth's surface. If we suppose the Earth to pass through a region of space where there are comparatively few meteors, the height of the atmosphere would in the course of time be greatly decreased, and we should have a temperature at the sea level corresponding to the present temperature of our mountain-tops. In the language of geologists, a glacial epoch would be the result. If, on the other hand, the Earth passed through a region of space rich in meteors, containing occluded carbonic acid gas, the atmosphere would increase in depth, and a period like the carboniferous period might be the result, in which a semi-tropical vegetation might again flourish on the coast of Greenland.

Observations of the Transit of Mercury, May 6, 1878, *and of the Occultation of Mars by the Moon, June* 3, 1878, *made at the Glasgow Observatory.* By Professor R. Grant, Director of the Observatory.

Transit of Mercury.

Observed by Mr. Arthur Bowden, Principal Assistant. The instrument used was the Ochtertyre Equatoreal of 9 inches aperture, with a magnifying power of 240 applied. The external contact at ingress was lost. As the planet advanced upon the Sun's disk, the instant of the bisection of its disk by the Sun's limb was observed to occur at $3^h\ 12^m\ 31^s$ Greenwich Mean Time. The internal contact was well seen. It occurred at $3^h\ 14^m\ 15^s{\cdot}7$ Greenwich Mean Time. A bright spot was distinctly seen on the disk of the planet a little before contact. It was well defined and appeared of the same colour as the Sun. When the planet had wholly entered upon the Sun the spot did not appear so bright, but as the Sun was all the time covered by a thin cirrus of constantly varying density, the difference in brightness of the spot may have been attributable to that cause. No indication of a ligament was perceptible at the time of the planet's entrance upon the Sun's disk, but immediately after internal contact the limb of the planet exhibited an elongation or distortion towards the Sun's limb. This appearance continued visible for about ten seconds after contact. The bright spot was seen only once after the

planet had advanced well on the Sun's disk. No appearance of a halo around the planet was visible, although the outline of the disk was carefully scanned, using in succession several magnifying powers.

Note by Professor Grant.—When the planet had wholly entered upon the Sun's disk I observed its appearance in the Ochtertyre Equatoreal. The disk was of a uniformly black colour and was exceedingly well defined. I failed to perceive any indication of the bright spot to which Mr. Bowden refers, nor could I discern the slightest trace of a nebulous ring around the planet.

Occultation of Mars by the Moon.

The phenomenon was observed by Professor Grant with the Ochtertyre Equatoreal, magnifying power 240. The final extinction of the planet's light occurred at $9^h\ 57^m\ 1^s$ Greenwich Mean Time. The reappearance was not seen.

Measures of the Diameter of Mercury made at the Princeton Observatory, May 6, 1878.

(*Communicated by Professor C. A. Young.*)

In a recent Number of the *Monthly Notices* (see vol. xxviii., p. 423) the result of a preliminary reduction of our observations was stated as $11''{\cdot}74$.

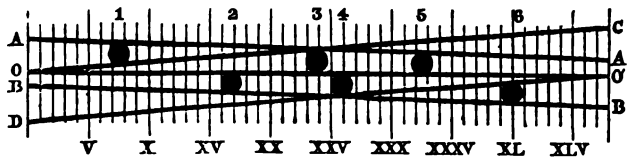
The rigorous reduction has changed this a little more than was anticipated, giving $11''{\cdot}705$ as the final result.

I had hoped to get a double-image micrometer in season for the Transit; but, failing to do so, adopted the method described below, which, so far as I know, is new and gives very satisfactory results.

The measures were made by bringing the image of the planet between two slightly converging bands or broad lines photographed on glass, and the observation consisted in noting the point where the disk exactly filled the interval between them. The bands were made nearly as wide as the planet, in order to neutralise irradiation. The plate upon which they were photographed was fitted into a micrometer in place of the usual spider-lines, and could be moved by the screw so as to bring any part of the plate to the centre of the field of view. The apparatus was attached to the Merz polarising eye-piece of the $9\frac{1}{2}$-inch Equatoreal, by which the intensity of the light could be graduated at pleasure. Powers of 150, 220, and 490 were used in the observations.

The arrangement of the reticule is indicated in the accompanying diagram, which, however, is not drawn to scale.

As will be seen, it affords six different points at which the measurements can be effected.



The plate was made as follows. A very careful drawing was constructed by Mr. Libbey, the base line OO′ being two feet long and accurately divided into half-inch spaces by a steel rule. This drawing was then photographed upon glass by Professor Brackett with a Dallmeyer rectilinear lens, which formed a reduced copy about half an inch long, distinct and sharp, and without the least distortion which could be detected by careful microscopic measurements made for the purpose. The slope of the bands A and B with reference to O was about 1 in 100, that of the bands C and D about 1 in 50.

The value of the graduated scale was ascertained by observing with the chronograph, on May 14, 16 transits of both limbs of the Sun over all the lines; the results were closely accordant and give—

1 div. (which is $0^{in}\cdot500$ on the original drawing) = $24''\cdot4996 \pm 0''\cdot0075$.

The distances between the bands at the points of measurement were determined in two ways: by direct measures of the glass plate under the microscope; and by measuring the original drawing with vernier callipers reading to thousandths of an inch. The two methods gave essentially the same result in every case; but the latter was preferred, as showing a smaller probable error.

The method pursued was as follows; taking, as an example, the measurement between A and O′ (No. 5 on the diagram):—

A moment's inspection of the record of observations shows that the mean result lies between 33 and 34 on the scale. Accordingly we measure, on the original paper drawing, the distance in thousandths of an inch between the adjacent edges of the bands A and O at the neighbouring graduation marks. The measurements were made by three different persons, and, the means being taken, we get the following numbers:—

At (31) the distance between A and O comes out $0^{in}\cdot2479$;
„ (32) „ „ „ $0^{in}\cdot2422$;
„ (33) „ „ „ $0^{in}\cdot2362$;
„ (34) „ „ „ $0^{in}\cdot2327$;
„ (35) „ „ „ $0^{in}\cdot2298$;
„ (36) „ „ „ $0^{in}\cdot2244$.

Each of these measurements gives an equation of condition of the form $x - ny = a$, when x is the corrected distance between A and O at (31), y is the change of distance corresponding to one division of the scale, and a is the measured distance at any scale division. Thus, for (36) the equation is $x - 57 = 0.2244$.

The equations of condition are then solved by the method of least squares, and, with the values of x and y thus found, a corrected series of distances is constructed. These distances are reduced to seconds by the relation

$$\delta = \frac{D}{500} \times 24''.4996,$$

where δ is the distance in arc, and D the distance in thousandths of an inch.

The numbers are then tabulated, and with their help the result of each measurement of the planet is obtained by a simple interpolation at sight.

In the example cited the results are as follows :—

Series 5, A and O.

Scale Division.	Measured distance.	Corrected.	Value.
			"
31	247·9	246·8	12·09
32	242·2	242·3	11·87
33	236·2	237·8	11·65
34	232·7	233·3	11·43
35	229·8	228·7	11·21
36	224·4	224·2	10 99

The observations were much interrupted by flying clouds; hence the incompleteness of several of the series. It was intended to make 8 measurements at each point, 4 of the equatoreal and 4 of the polar diameter, but the fourth measurement of the polar diameter failed. The results of the six series are given below :—

(1) Between A and C.		(2) Between B and O.	
Equat. Diam.	Polar Diam.	Equat. Diam.	Polar Diam.
"	"	"	"
11·14	11·47	11·28	12·12
11·81	11·94	11·40	11·74
11·94	11·60	12·00	11·83
12·01		11·88	
Mean 11·73	11·67	Mean 11·64	11·90

(3) Between C and O.

Equat. Diam.	Polar Diam.
11·49	12·00
12·10	11·75
11·80	
11·64	
Mean 11·76	11·87

(5) Between A and O.

Equat. Diam.	Polar Diam.
11·19	11·91
11·87	11·54
11·83	11·65
11·61	11·43
Mean 11·62	11·63

(4) Between D and O.

Equat. Diam.	Polar Diam.
11·81	11·91
12·02	11·40
11·40	
11·76	
Mean 11·75	11·66

(6) Between B and D.

Equat. Diam.	Polar Diam.
11·67	11·87
12·13	11·53
11·67	11·33
11·46	
Mean 11·73	11·58

Mean of Equatoreal measures	11·704.
„ Polar „	11·707.
General mean	11·705 ± 0″·030.

The equatoreal diameter, so called above, is merely the diameter parallel to the celestial equator, and the polar that at right angles to it.

If we reduce the result to distance unity, we get 6″·524, which corresponds to a diameter of 2,290 miles, assuming the solar parallax at 8″·85.

Mr. Libbey and Professor Rockwood also made a few observations: from the measurements of the former we get 11″·56, from those of the latter 11″·76. On the whole, I have thought it best, however, not to incorporate them with my own.

Princeton, N.J.,
1878, *November* 12.

Note on Some Remarks of Mr. Maxwell Hall on the Opposition of Mars. By David Gill, Esq.

In the last Number of the *Monthly Notices** Mr. Maxwell Hall has objected to the method of observing *Mars* with the heliometer as inferior in accuracy to the method of transits employed by him.

* This paper was communicated in November, along with Mr. Gill's papers which appeared in the last two Numbers of the *Monthly Notices*.—Ed.

I do not object to this criticism if Mr. Maxwell Hall can show that his results have smaller probable error and greater freedom from systematic error than mine. When his results are published it will be time enough to examine this question. I concede at once the advantages which the method of Mr. Hall affords in simplicity of reduction; but it appears to me that, when an exceptionally favourable opportunity, like the late opposition of *Mars*, occurs, the question is not what is the *easiest*, but what is the *best* method to observe it.

I object very strongly, however, to the proof which Mr. Maxwell Hall puts forward as to the accuracy of his observations. He contends that his observations are so accurate that by their means he has succeeded in determining the variation of the rate of his clock in short intervals, and makes the rather extraordinary statement that, though the rate of his clock may be relied upon from day to day for uniformity of rate to half a second, yet it varies two or three tenths of a second in intervals of ten or fifteen minutes. I am very much puzzled to find how Mr. Hall arrives at this conclusion and how he distinguishes between errors of observation and errors of clock rate.

The only proof of the supposed errors of his clock rate he finds in the various different values of the difference of R.A. between the same comparison stars obtained from observations at different times. It is obvious that these differences may be caused either by error in clock rate or by errors of observation; and, from the observations only, it seems to me impossible to say definitely to which of the two causes the discordances must be attributed. But, from what I know of clocks and their rates, the probabilities appear to me exceedingly strong that Mr. Hall himself is more likely to have made the errors in question than his clock. With regard to Mr. Hall's remarks which appear to imply that undue time has been occupied in my reductions, I think that the papers I have laid before the Society to-night are their best answer.

On the Observed Errors of Bouvard's Tables of Saturn.

By E. Dunkin, F.R.S.

During the discussion at the December meeting, after the reading of the Astronomer Royal's paper on the approaching conjunction of *Mars* and *Saturn*, reference was made to the large errors of Bouvard's Tables, on which the tabular places of *Saturn* given in the *Nautical Almanac* for 1879 depend. On that occasion I made a remark that the tabular errors of *Saturn*, deduced at Greenwich from recent observations, are not really so large as indicated by a direct comparison of the corresponding places inserted in the *Nautical Almanac* for 1879 and 1880, derived respectively from the Tables of Bouvard and Le Verrier. It

appears to me that the subject is sufficiently interesting to make it desirable to place on record in the *Monthly Notices* the actual amount of the observed tabular errors of *Saturn* during the last few years, determined from the Greenwich observations. On an examination of these errors, it will be perceived that their magnitude has been increasing of late, and the numbers in the following Table point to a further increase in the present year, though we can hardly anticipate that the amount of error will reach that found from the single comparison between the Tables of Bouvard and Le Verrier.

The numbers given below have been deduced from the Greenwich observations made near opposition, and when *Saturn* passed the meridian near 6^h, or near the time of the planet's quadrature with the Sun. From the observed errors of geocentric longitude and ecliptic polar distance of *Saturn* for the last eleven years, beginning with 1868, I have calculated the angular distances between the observed places and the tabular places, from which the general magnitude of the error from year to year can be easily seen. These, with the observed errors in R.A. and N.P.D., are given in the Table.

Year.	From Mean of Group nearest Opposition. Error in R.A.	Error in N.P.D.	Difference between Observed and Tabular Places.	From Mean of Group nearest 6^h M.T. Error in R.A.	Error in N.P.D.	Difference between Observed and Tabular Places.
	s	"	'	s	"	"
1868	−0·50	+ 5·02	8·8	−0·60	+ 3·51	9·1
1869	−0·86	+ 2·81	12·4	−0·94	+ 0·87	13·4
1870	−0·89	+ 1·65	12·5	−0·83	+ 0·44	12·3
1871	−0·86	− 0·31	12·0	−0·56	− 1·07	7·8
1872	−0·71	− 1·49	10·0	−0·34	− 2·72	5·5
1873	−0·75	− 3·52	11·1	−0·25	− 4·92	6·1
1874	−0·60	− 4·12	9·6	−0·16	− 6·50	6·9
1875	−0·78	− 6·72	13·2	−0·25	− 8·30	9·1
1876	−0·83	− 5·65	13·5	−0·18	− 9·24	9·7
1877	−0·62	− 8·92	12·8	−0·27	−10·43	11·2
1878	−0·77	− 8·03	14·1	−0·52	− 8·60	11·5
Corresponding numbers deduced from the *Nautical Almanac*, 1879-80.						
1879				−1·44	− 3·00	21·9

Assuming Le Verrier's Tables of *Saturn* to be correct, the tabular error of Bouvard's Tables in geocentric longitude on 1880, January 1, is $-18''\cdot72$, and that of ecliptic north polar distance is $-11''\cdot26$, equivalent to a difference of $21''\cdot9$ between the separate places as derived from the old and new Tables. On this day *Saturn* passes the meridian of Greenwich at $5^h\ 55^m$

M.T., and this difference therefore becomes comparable with the numbers in the last column deduced from observation.

Though the tabular error of Bouvard's Tables appears to be increasing at the present time, we should hardly expect to find so great an increase as 10″ in the interval between December 1878 and December 1879, viewed in conjunction with the column of errors determined from observations made near 6^h; and may we not therefore assume that the large difference found between the two calculated places for 1880, January 1, is partly due to small outstanding errors in the new Tables?

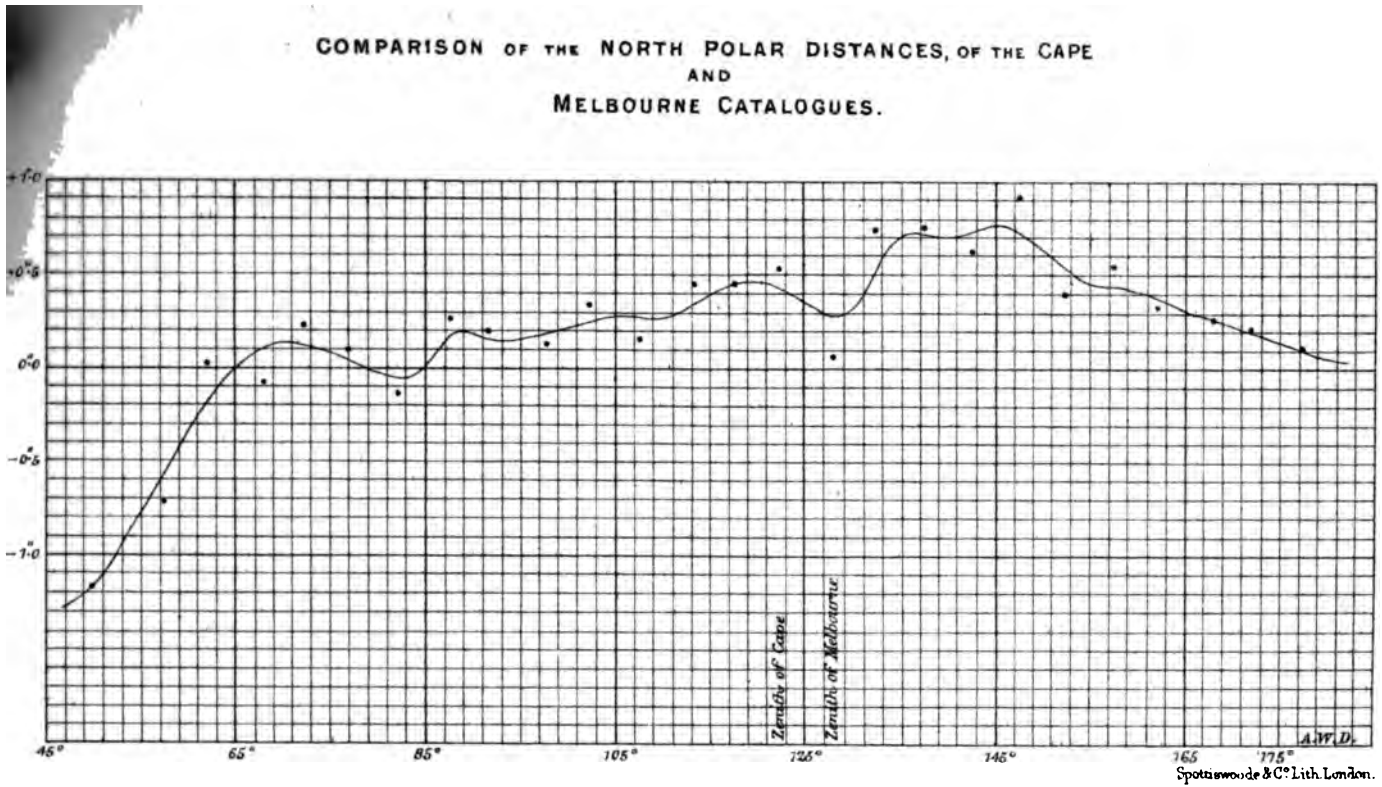
Blackheath,
1879, *January* 4.

On the Reduction of the North Polar Distances of the First Melbourne General Catalogue for 1870 *to Auwers' Standard.*

By A. W. Downing, B.A. (Dublin).

This investigation consists essentially of a comparison of the North Polar Distances of the Cape Catalogue for 1860 with those of the Melbourne Catalogue. The reduction of the latter to the Standard is then accomplished by applying to the differences Cape—Melbourne for different N.P.D.'s the corrections applicable to the N.P.D.'s of the Cape Catalogue to reduce them to the Standard, which I have given in a former paper, printed in the *Monthly Notices* for December 1878.

There are 352 stars common to the Cape and Melbourne Catalogues which are available for the comparison, after rejecting those whose places in either Catalogue depend on a single observation. I have also rejected *α Centauri* and another star which gave a discordant result. As the southern stars have generally been reduced to the mean epochs of the Catalogues with different proper motions in each Catalogue, it has been necessary to correct the places given in one of the Catalogues for the difference, and the proper motion given in the Cape Catalogue has been adopted as the one to be used, except in those cases in which this proper motion is taken from the B.A.C., when the value given in the Melbourne Catalogue has been used in preference. The places in the Cape Catalogue have then been brought up to 1870, with the precessions given in this Catalogue and the adopted proper motion, and the difference taken between the N.P.D. thus obtained and that given in the Melbourne Catalogue, corrected, if necessary, for assumed proper motion. The 352 stars, having been arranged in order of N.P.D., have been taken in groups, each group embracing about 5°, and the means taken of the N.P.D.'s and of the differences between the Catalogues for each group. These mean differences have been


COMPARISON OF THE NORTH POLAR DISTANCES, OF THE CAPE
AND
MELBOURNE CATALOGUES.
+1·0
+0·5
0·0
−0·5
−1·0
45°
65°
85°
105°
125°
145°
165
175°
Zenith of Cape
Zenith of Melbourne
A.W.D.
Spottiswoode & C° Lith. London.

laid down and a curve (*see* diagram) drawn through the points, which may be taken as representing the systematic differences between the Catalogues.

The following Table gives the differences as computed and as read off from the curve:—

N.P.D.		Number of Stars.	C−M.	
°	′		Computed. ″	Curve. ″
49	51	4	−1·17	−1·17
57	13	3	−0·71	−0·59
62	10	10	+0·03	−0·20
67	56	9	−0·08	+0·09
72	14	7	+0·22	+0·12
77	5	12	+0·10	+0·04
82	23	14	−0·12	−0·06
87	20	11	+0·28	+0·16
91	47	10	+0·20	+0·16
97	52	8	+0·12	+0·18
102	39	5	+0·34	+0·25
107	22	9	+0·16	+0·26
113	3	7	+0·46	+0·34
117	37	20	+0·45	+0·45
122	24	12	+0·53	+0·44
127	45	20	+0·07	+0·28
132	25	30	+0·74	+0·53
137	18	25	+0·77	+0·71
142	46	14	+0·62	+0·73
147	36	20	+0·92	+0·72
152	27	21	+0·40	+0·52
157	19	28	+0·53	+0·44
162	19	6	+0·32	+0·37
168	9	14	+0·27	+0·27
172	15	20	+0·21	+0·19
177	13	13	+0·12	+0·11

The differences have then been read off from the curve for every 4°, and the correction to the Cape N.P.D. to reduce it to the Standard (or to Henderson, for stars south of N.P.D. 120°) applied. The result is given in the two following Tables:—

TABLE I.—*Reduction to Auwers' Standard.*

N.P.D. °	C−M. "	Standard−M. "	N.P.D. °	C−M. "	Standard−M. "
48	−1·25	−0·87	88	+0·17	+0·29
52	−1·05	−0·78	92	+0·14	+0·33
56	−0·70	−0·55	96	+0·17	+0·42
60	−0·35	−0·22	100	+0·22	+0·44
64	−0·05	+0·03	104	+0·27	+0·35
68	+0·10	+0·12	108	+0·26	+0·20
72	+0·12	+0·10	112	+0·30	+0·09
76	+0·06	−0·02	116	+0·43	+0·27
80	−0·03	−0·09	120	+0·46	+0·21
84	−0·04	−0·02	124	+0·37	+1·97

TABLE II.—*Reduction to Henderson.*

N.P.D. °	C−M. "	H−M. "	N.P.D. °	C−M. "	H−M. "
120	+0·46	+1·70	152	+0·55	+0·11
124	+0·37	+1·54	156	+0·44	−0·02
128	+0·28	+1·24	160	+0·41	+0·09
132	+0·47	+1·00	164	+0·34	−0·02
136	+0·72	+0·83	168	+0·27	−0·20
140	+0·70	+0·55	172	+0·19	−0·24
144	+0·76	+0·71	176	+0·12	−0·18
148	+0·69	+0·51	180	+0·06	−0·02

This reduction to Henderson is of course provisional only. I hope that, when Mr. Stone's great Catalogue is published, it will be possible to deduce a system of Standard North Polar Distances for Southern Stars analogous to that given by Dr. Auwers for stars visible in European latitudes.

Greenwich,
1879, *Jan.* 7.

Phenomena of Jupiter's Satellites, 1877–78, *observed at Stonyhurst Observatory*. By the Rev. S. J. Perry.

1877	Sat.	Phenomenon.	G.M.T. h	m	s	Remarks.
July 24	II	Occ. D. last contact	11	11	34·2	Poor; definition very bad; tremulous.
1878						
June 26	IV	Ec. R. first contact	14	50	14·0	Passing clouds; strong daylight.
27	III	Tr. egress, bisection	13	29	34·6	
		last contact		33	24·1	
29	III	Occ. D. first contact	12	35	30·5	Very unsteady.
		bisection		39	29·5	
		last contact		42	45·7	
Aug. 10	I	Tr. E. first contact	10	43	46·6	
		bisection		47	29·6	
		last contact		49	46·1	
25	I	Occ. D. first contact	9	14	4·1	
		bisection		15	47·0	
		last contact		17	5·5	
	I	Ec. R. first seen	12	19	31·2	
Sept. 9	I	Occ. D. first contact	9	56	54·2	Cloudy; definition very bad.
		bisection	10	0	0·7	
		last contact		2	51·7	
10	I	Occ. D. first contact	7	14	6·9	
		bisection	7	16	51·4	
		last contact	7	18	47·2	
	III	Occ. D. bisection	9	3	13·9	
		last contact	9	6	18·4	
	I	Ec. R.	10	38	42·4	Hazy.
20	II	Occ. D. first contact	8	53	26·9	
		bisection	8	55	42·4	
		last contact	8	58	19·4	Seen within the limb for about 45″ after this.
Nov. 4	I	Ec. R.	7	32	17·4	

The above observations were all made by Mr. W. Carlisle; and the shortness of the list is due mainly to the absence of the object-glass, which has been very successfully repolished by Mr. J. Simms, who felt confident that the spherical aberration could be fairly removed in the process.

Observations of Occultations of Stars by the Moon, and of Phenomena of Jupiter's Satellites, made at the Royal Observatory, Greenwich, in the Year 1878.

(*Communicated by the Astronomer Royal.*)

Occultations of Stars by the Moon.

Day of Obs. 1878.		Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
Mar. 16		Disapp. of A Leonis	Altaz.	100	Dark	9 57 16·5	T
June 5		,, π^2 Cancri	E. Eq.	140	,,	8 54 16·6	,,
Sept. 6		,, λ^1 Sagittarii	,,	,,	,,	7 32 27·8	HP
Nov. 10	(*a*)	,, 17 Tauri	S.E. Eq.	285	Bright	9 31 19·5	WC
,,	(*b*)	,, 20 Tauri	,,	,,	,,	10 23 17·0	,,
,,	(*c*)	Reapp. 17 Tauri	,,	,,	Dark	10 46 40·9	,,
,,		Disapp. η Tauri	E. Eq.	140	Bright	11 11 16·0	GP

Notes.

(*a*) The star disappeared gradually in a sort of luminous haze surrounding the Moon's limb, which seemed to retire from the star for a space of three or four seconds of time. Just before disappearing the star was seen apparently bisected by the limb.

(*b*) The star disappeared gradually at the Moon's bright limb; observed with a graduated dark shade.

(*c*) Reappeared instantaneously.

Phenomena of Jupiter's Satellites.

Day of Obs. 1878.		Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time from *N.A.* h m s	Observer.
July 4		III	Tr. ing. first contact	E. Eq.	140	13 8 26·2	13 12	C
17		I	Occ. reapp. first contact	,,	,,	13 58 45·8		
,,		I	,, bisection	,,	,,	14 0 15·5	14 0	AD
,,		I	,, last contact	,,	,,	14 2 0·2		
18		I	Tr. egr. last contact	,,	,,	11 7 18·4	11 10	T
,,		II	Ecl. disapp.	,,	,,	11 58 50·0	11 59 43	,,
29		III	Occ. disapp. first contact	,,	,,	12 40 49·5	12 41	C
Aug. 17	(*d*)	I	Tr. ing. first contact	S.E. Eq.	220	10 11 23·7		
,,		I	,, bisection	,,	,,	10 14 5·2	10 12	M
,,		I	,, last contact	,,	,,	10 16 24·8		
,,	(*e*)	I	Tr. egr. first contact	,,	,,	12 28 24·2		
,,		I	,, bisection	,,	,,	12 30 58·8	12 32	,,
,,		I	,, last contact	,,	,,	12 33 33·3		

Day of Obs. '1878.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time from *N.A.* h m s	Observer.
Aug. 19 (*f*)	II	Occ. disapp. first cont.	E. Eq.	140	10 16 59·5		
„	II	„ bisection	„	„	10 19 4·1	10 21	R
„	II	„ last cont.	„	„	10 21 13·8		
26 (*g*)	I	Tr. egr. first contact	„	„	8 40 29·1		
„	I	„ last contact	„	„	8 43 19·7	8 44	C
27 (*h*)	III	Ecl. reapp. first seen	S.E. Eq.	220	8 43 2·5		
„	III	„ dichotomised	„	„	8 44 52·2	8 45 54	M
„	III	„ full brightness	„	„	8 46 51·9		
Sept. 3 (*i*)	I	„ first seen	„	„	8 43 18·4		
„	I	„ full brightness	„	„	8 44 39·2	8 43 16	WC
„ (*k*)	III	Occ. reapp. first appearance	„	„	9 1 43·4		
„	III	„ bisection	„	„	9 3 26·1	9 8	„
„	III	„ last contact	„	„	9 4 55·8		
„	III	Ecl. disapp. first obs.	„	„	9 12 54·5		
„ (*l*)	III	„ disappearance	„	„	9 16 38·9	9 18 4	„
6 (*m*)	II	Ecl. reapp. first seen	E. Eq.	140	8 58 5·0		
„	II	„ half brightness	„	„	8 59 12·8	8 58 39	HP
„	II	„ full brightness	„	„	9 0 2·7		
18 (*n*)	I	Tr. egr. first contact	S.E. Eq.	220	8 32 46·2		
„	I	„ bisection	„	„	8 36 0·6	8 36	M
„	I	„ last contact	„	„	8 39 5·1		
„ (*o*)	I	„ last contact	E. Eq.	140	8 41 11·7	8 36	W
„	IV	Ecl. reapp. first seen	S.E. Eq.	220	9 25 9·3		
„ (*p*)	IV	„ dichotomised	„	„	9 28 47·0	9 34 49	M
„	IV	„ full brightness	„	„	9 32 56·3		
„ (*q*)	IV	„ first seen	E. Eq.	140	9 27 59·0		
„	IV	„ dichotomised	„	„	9 29 33·7	9 34 49	W
„ (*r*)	IV	„ first seen	Altaz.	100	9 29 38·1	9 34 49	C
19	I	„ first seen	„	„	7 3 3·9	7 2 45	R
20	II	Occ. disapp. first cont.	E. Eq.	140	8 57 3·8		
„	II	„ last contact	„	„	9 0 18·2	8 58	C
26 (*s*)	IV	Tr. egr. last contact	S.E. Eq.	220	8 6 0·5	8 25	WC
„ (*t*)	I	Ecl. reapp. first seen	„	„	8 58 3·9		
„	I	„ half brightness	„	„	8 58 51·8	8 58 7	„
„	I	„ full brightness	„	„	9 0 1·6		
„	I	„ first seen	E. Eq.	140	8 58 14·8		
„	I	„ half brightness	„	„	8 59 17·7	8 58 7	J
„	I	„ full brightness	„	„	9 0 27·5		

Day of Obs. 1878.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time from *N.A.* h m s	Observer
Oct. 11 (*u*)	I	Tr. ing. first contact	S.E. Eq.	285	6 22 2·3		
,,	I	,, bisection	,,	,,	6 24 31·9	6 20	M
,,	I	,, last contact	,,	130	6 26 41·6		
18	I	Tr. ing. first contact	E. Eq.	140	8 11 41·6		
,,	I	,, bisection	,,	,,	8 14 41·1	8 15	J
,,	I	,, last contact	,,	,,	8 18 20·5		
23 (*v*)	III	Occ. disapp. bisection	S.E. Eq.	220	7 52 12·0	7 58	WC
24 (*w*)	II	Tr. egr. last contact	E. Eq.	140	6 34 41·5	6 28	AD
Nov. 2	II	Ecl. reapp. first seen	,,	70	5 56 0·6		
,,	II	,, full brightness	,,	140	5 58 24·2	5 56 25	,,
11 (*x*)	I	Occ. disapp. first contact	,,	,,	5 54 54·2		
,,	I	,, bisection	,,	,,	5 55 44·1	5 55	,,
,,	I	,, last contact	,,	,,	5 56 48·9		

Notes.

(*d*) *Jupiter* was occasionally very well defined, especially at the first contact. The limb of the planet became afterwards very boiling and rugged. The satellite was very brilliant on the disk.

(*e*) Limb tremulous. The satellite did not appear so bright as at ingress.

(*f*) The planet well defined.

(*g*) The image of the planet very bad.

(*h*) *Jupiter* and the satellites were very tremulous. The time noted at "first seen" may be two or three seconds late.

(*i*) Pretty exact; a very minute speck when first seen; the Airy eye-piece used throughout.

(*k*) The time noted at first appearance is pretty exact.

(*l*) A very faint speck at time of disappearance.

(*m*) Satisfactory.

(*n*) Very tremulous, especially at the last contact.

(*o*) The image very diffused; the observation difficult.

(*p*) The times recorded at "dichotomised" and at "full brightness" were a little early; probably they should be increased by 20^s. Images very tremulous.

(*q*) Rather late; the time recorded at full brightness is also uncertain, owing to tremor and diffusion.

(*r*) Not certain; thin clouds were contiuually passing.

(*s*) The satellite was not seen a few minutes before the last contact when on the disk. Definition very bad. The Airy eye-piece used.

(*t*) Increased very rapidly in brightness in the next two or three seconds.

(*u*) Very tremulous; definition bad.

(*v*) Not satisfactory; the planet was only seen for about a minute, the sky being cloudy at the first and last contacts. The Airy eye-piece used.

(*w*) The first phases could not be observed, owing to the bad image.

(*x*) Definition good.

The clear aperture of the object-glass of the S.E. Equatoreal is 12¾ inches, of the East Equatoreal 6·7 inches, and of the Altazimuth 3¾ inches.

The initials WC, C, AD, M, T, W, HP, R, GP, and J, are those of Mr., Christie, Mr. Criswick, Mr. Downing, Mr. Maunder, Mr. Thackeray, Mr. Wickham, Mr. Pead, Mr. Robinson, Mr. Pearce, and Mr. James.

Royal Observatory, Greenwich,
1878, *December* 31.

Ephemerides for Determining the Positions of the Satellites of Uranus, 1879.

By A. Marth, Esq.

Angles of position, p, of the major axes and logarithms of the major and minor semi-axes, a and b, of the apparent orbits of the satellites.

Greenwich. Noon. 1879.		Ariel.		Umbriel.		Titania.		Oberon.	
	p_o	log a	log b	log a	log b	log a	log b	log a	log b
	°								
Jan. 25	13·03	1·1808	0·5110	1·3248	0·6550	1·5397	0·8699	1·6660	0·9961
30	12·99	·1818	·5185	·3258	·6625	·5407	·8774	·6669	1·0036
Feb. 4	12·95	·1825	·5260	·3265	·6699	·5414	·8848	·6677	·0111
9	12·90	·1831	·5334	·3271	·6774	·5420	·8923	·6682	·0185
14	12·85	·1835	·5407	·3275	·6847	·5424	·8996	·6686	·0258
19	12·81	·1837	·5479	·3277	·6918	·5426	·9068	·6688	·0330
24	12·76	·1837	·5547	·3277	·6967	·5426	·9136	·6688	·0399
Mar. 1	12·71	1·1835	0·5613	1·3275	0·7052	1·5424	0·9201	1·6686	1·0464
6	12·66	·1831	·5674	·3271	·7113	·5420	·9262	·6683	·0525
11	12·61	·1826	·5730	·3265	·7170	·5414	·9319	·6677	·0581
16	12·57	·1818	·5781	·3258	·7221	·5407	·9370	·6669	·0631
21	12·52	·1809	·5826	·3249	·7266	·5398	·9415	·6660	·0677
26	12·48	·1798	·5866	·3238	·7305	·5387	·9455	·6649	·0717
31	12·44	·1786	·5899	·3225	·7339	·5375	·9488	·6637	·0750
Apr. 5	12·41	1·1772	0·5925	1·3212	0·7365	1·5361	0·9514	1·6623	1·0777
10	12·38	·1757	·5945	·3197	·7385	·5346	·9534	·6608	·0797
15	12·36	·1741	·5959	·3180	·7399	·5330	·9548	·6592	·0810
20	12·34	·1724	·5966	·3163	·7405	·5312	·9554	·6575	·0817
25	12·32	·1706	·5966	·3145	·7405	·5294	·9555	·6557	·0817
30	12·31	·1687	·5959	·3127	·7399	·5276	·9548	·6538	·0810
May 5	12·30	1·1668	0·5946	1·3107	0·7386	1·5257	0·9535	1·6519	1·0798
10	12·30	·1648	·5927	·3088	·7367	·5237	·9516	·6499	·0778
15	12·31	·1628	·5902	·3068	·7341	·5217	·9490	·6480	·0753
20	12·32	·1608	·5870	·3048	·7309	·5197	·9459	·6460	·0721
25	12·34	1·1589	0·5832	1·3028	0·7271	1·5178	0·9420	1·6440	1·0683

Longitudes of the satellites in their orbits reckoned from the points where they are at their greatest northern elongations.

Greenwich, Noon.	Ariel. long.	diff.	Umbriel. long.	diff.	Titania. long.	diff.	Oberon. long.	diff.
	°	°	°	°	°	°	°	°
Jan. 25	39·65		26·09		327·57		329·31	
		714·18		434·33		206·74		133·67
30	33·83		100·42		174·31		102·98	
		·17		·33		·73		·67
Feb. 4	28·00		174·75		21·04		236·65	
		·16		·32		·73		·67
9	22·16		249·07		227·77		10·32	
		·16		·32		·72		·67
14	16·32		323·39		74·49		143·99	
		·15		·32		·73		·66
19	10·47		37·71		281·22		277·65	
		·14		·31		·72		·67
24	4·61		112·02		127·94		51·32	
		·14		·31		·72		·66
Mar. 1	358·75		186·33		334·66		184·98	
		·14		·30		·72		·66
6	352·89		260·63		181·38		318·64	
		·13		·30		·72		·67
11	347·02		334·93		28·10		92·31	
		·12		·30		·73		·66
16	341·14		49·23		234·83		225·97	
		·12		·30		·72		·66
21	335·26		123·53		81·55		359·63	
		·12		·30		·72		·67
26	329·38		197·83		288·27		133·30	
		·11		·30		·72		·67
31	323·49		272·13		134·99		266·97	
		·11		·30		·72		·67
Apr. 5	317·60		346·43		341·71		40·64	
		·11		·29		·73		·67
10	311·71		60·72		188·44		174·31	
		·11		·30		·73		·67
15	305·82		135·02		35·17		307·98	
		·11		·30		·73		·68
20	299·93		209·32		241·90		81·66	
		·11		·30		·73		·68
25	294·04		283·62		88·63		215·34	
		·11		·30		·73		·68
30	288·15		357·92		295·36		349·02	
		·12		·31		·74		·69
May 5	282·27		72·23		142·10		122·71	
		·11		·30		·74		·68
10	276·38		146·53		348·84		256·39	
		·12		·31		·74		·69
15	270·50		220·84		195·58		30·08	
		·12		·31		·75		·70
20	264·62		295·15		42·33		163·78	
		714·12		434·32		206·75		133·70
25	258·74		9·47		249·08		297·48	

These values are to be interpolated for the times for which the positions of the satellites are required. The position angles, p, and distances, s, are then found by means of the equations—

$$s \sin (p_o - p) = b \sin \text{long.}$$
$$s \cos (p_o - p) = a \cos \text{long.}$$

Notes on the late Admiral Smyth's "Cycle of Celestial Objects," Volume the Second, commonly known as the "Bedford Catalogue."
By Herbert Sadler, Esq.

In the year 1844 Admiral (then Captain) Smyth published his *Cycle of Celestial Objects*, for the second volume of which, commonly known as the "Bedford Catalogue," the author in the ensuing year received the Gold Medal of the Society. I may be mistaken, but it seems to me that the Presidential Address on that occasion is couched in eminently cautious language as to the exactness of the micrometrical measures in Admiral Smyth's work. If this be the case, it has been abundantly justified by the results. The following facts may perhaps convey some idea of the intrinsic value of the measures recorded therein. In the first hour of right ascension there are 108 measures (54 of the position angles and 54 of the distances) of 36 different objects, being stars with comites, double, triple, or multiple stars. Of these 108 measures, no less than 32 have the mark "w^1" attached to them; a weight, as the author himself observes, representing nearly worthlessness. More than this, 12 out of these 36 objects have this weight assigned to the measures both of their position angles and distances, so that the measures of *one-third* of the objects in the first hour of R.A. are avowedly useless for any practical purpose, and there is a residuum of 8 more such measures to be distributed amongst the remaining 24 objects. On presenting the medal, the Astronomer Royal, observing that the character of the Council was most deeply pledged in the award, requested that Captain Smyth would present the original observations on which the Catalogue was based to the Society, in order that, if occasion should arise, these MSS. might be readily consulted by any Fellow. In presenting these, Captain Smyth wrote as follows: "Previously, however, to its removal [from Hartwell], a most careful scrutiny has been instituted of the slips and other papers with the printed *Cycle*, and various typographical errors have been detected in consequence. Some printed lists of these are herewith forwarded for any Fellows of the Society who may possess a copy of the work." As possibly every copy of the *Cycle* does not possess this list, I have transcribed the portion relating to vol. ii., and inserted it at the end of these Notes. Some few years ago, being much interested at the time in certain stars of the "Bedford Catalogue" which had apparently disappeared, I took the earliest opportunity I had of examining these original MSS., and was astounded to find the most extraordinary discrepancies between the printed Catalogue and the originals—discrepancies which at once accounted for the apparent anomalies. About the same time Mr. Burnham was sending to the *English Mechanic* some most admirable and searching criticisms on

Smyth's measures. As the opinion of so eminent an observer will carry deserved weight with it, I may be permitted to quote the following words from one of his letters on the subject: "No publication of original observations, in this or in any other language, can be named which contains so many serious errors. The measures of the Struves, Dembowski, Dawes, Secchi, and half a dozen others whose names might be mentioned, do not contain altogether more than a small fraction of the mistakes in the *Cycle* which have led to so much discussion and confusion. . . Ordinarily there is no difficulty in detecting the mistake at once. This is not the case with the *Cycle*. There is no theory which will account for the many serious discrepancies. The measures generally agree substantially with those which are given from prior observers, but the strangest part is that this agreement is kept up just the same where the earlier measures were all wrong." As far as I am aware, there is one Catalogue only, and that not an original one, which surpasses the "Bedford Catalogue" in inaccuracy, and that Catalogue is the "Reference Catalogue of Multiple and Double Stars," forming vol. xl. of the *Memoirs*. I have not included in my Notes any notices of errors in Smyth's measures of three or four seconds of arc in the distances, or two or three degrees in the position angles, such as those that occur in the measures of the companions of ζ *Persei*, 72 *Virginis*, 15 *Hydræ*, γ *Aquarii*, and many other stars; nor have I alluded to mistakes in the magnitudes, alignments, diagrams, or descriptions, as such a course would have swelled these notes to an inconvenient length, and, indeed, would have been almost superfluous, as the proven inaccuracy of so many measures throws the greater doubt on all the others. Sir George Airy, in his address on the occasion of presenting the Gold Medal to Admiral Smyth, observed: "When the question shall be put regarding the measures of the 'Bedford Catalogue,' made at a critical time, and on which a future theory may hinge—Can these numbers be trusted with certainty to one or two-tenths of a second?—shall we be able to answer—Without doubt they can." Of this the Council were apparently satisfied, or else they would presumably not have awarded the medal to Admiral Smyth. I have thought it better, therefore, as the charge I have brought against the Bedford Catalogue is of a very serious character, to place an asterisk against the symbol of the observer whose erroneous measure Smyth appears to have followed, so that anyone may be able to detect the source of Smyth's error at a glance in cases where he has presumably copied the measures of others; but, for the sake of brevity, I have only given one or two correct measures for comparison. The symbols used are those commonly employed.

1878, *Dec.* 13.

α *Cassiopeiæ*. *Cycle*, No. 20.

	°	″	
H.	275·4	56·2	1781·97
*H_2.	278·8	90· ±	IV. Cat.
Sm.	278·4	96·9	1831·86
Ja.	279·5	61·4	1856·7

Sm. says (*Cycle*, p. 12): "The difference in distance is so remarkable that it must be imputed to instrumental error [on the part of H] rather than that the acolyte is describing an ellipse round its primary." He re-examined it in 1851, on a friend's pointing out the mistake to him, and deduced a result closely agreeing with Jacob's. (*Spec. Hart.*, p. 217.)

P. I. 222. *Arietis*. *Cycle*, No. 78.

	A-B °	A-B ″	A-C °	A-C ″	A-D			A m	B m	C m	D m
Σ.	53·5	2·4	167·4	39·5	caret	caret	1832·4	8·5	11·0	9·2	caret.
Sm.	53·0	2·5	165·0	40·0	359·2	165·0	1834·9	6	15	10	9
D.	53·7	2½	165·6	36·2	1·6	182·5	1862·9	9	10½	9½	6½

(*Cf. Monthly Notices*, vol. xxiii., pp. 11, 78, 93.) Smyth's diagram agrees exactly with his description of this object in the Bedford Catalogue. Kn. gives 183″·7 for distance of D, (1862·9).

55 *Cassiopeiæ*. *Cycle*, No. 84.

Hind gives $0^h\ 18^m\ 2^s{\cdot}1$ +63° 28′ 17″ (1878·0) for the place of *Nova* 1572, after D'Arrest.

θ *Persei*. *Cycle*, No. 109.

	A-C °	A-C ″	
Sm.	219·0	27·0	1833·6
Flam.	218·5	68·0	1877·6

Smyth's diagram agrees with his published results. His distance is totally erroneous, and is probably owing to H's remark that there is a third star *within* 1′.

γ *Persei*. *Cycle*, No. 124.

	°	″	
*H_2.	224·9	60	Vth Cat.
Sm.	226·0	55·0	1837·6
Bu.	324·1	caret	1876

Typographical error in Herschel's Vth Catalogue of 224°·9 for 324°·9, which Smyth has followed.

β Persei. Cycle, No. 127.

	°	″	
Sm.	195·0	55·0	1835·6
Bu.	192·4	81·9	1878·6

I do not know of any other observations of this star. Smyth's distance is evidently erroneous.

19 *Pleiadum. Cycle*, No. 138.

	°	″	
Sm.	335·0	45·0	1835·01
Main.	331·1	64·6	1863·1

I have not seen any other measures.

τ Orionis. Cycle, No. 196.

	A-B		A-C		
	°	″	°	″	
*H_2	250·4	18·0	63·8	18·0	Vth Cat.
Sm.	255·0	15·0	65·0	20·0	1835·9
Bu.	250·1	35·98	59·8	35·97	1878·2

Burnham has found B to be a close double. Smyth has followed Herschel II.

ν Aurigæ. Cycle, No. 229.

	°	″	
H_2.	208·2	53·72	1782·7
Sm.	201·9	85·0	1833·7
Bu.	207·0	55·0	1877·8

331°·80 in *Hh.* (p. 82) is a mistake. Sm. remarks: "The discordance in the distance is very great."

α Orionis. Cycle, No. 231.

	°	″	
*H_2.	152·3	161·8	1780·9
Sm.	155·0	160·0	1832·7
Bu.	152·3	174·7	1877·9

θ Aurigæ. Cycle, No. 233.

	°	″	
*H_2.	286·0	35·3	1782·7
Sm.	289·0	30·0	1832·6
OΣ.	290·5	48·3	1852·1
Bu.	292·7	45·5	1878·0

OΣ has lately discovered A to be a close double (5°·5 : 2″·15, '71). There are several other comites.

β Canis Majoris. Cycle, No. 246.

	°	"	
Sm.	339·0	104·0	1833·7
Bu.	339·7	183·9	1877

Smyth's distance is preposterous.

61 *Geminorum. Cycle*, No. 286.

	A-B °	A-B "		A m	B m
Sm.	110·0	60·0	1835·8	7½	9

Mr. Webb mentions (*Monthly Notices*, xxxv., p. 340; *Celestial Objects* (3rd edition), p. 247) that on two occasions, in 1852 and 1855, he failed to see Smyth's 9^{m} star. On the latter occasion, however, he found an exceedingly minute star, at about the right distance, with an estimated position angle of 185° or 190°. Mr. Knott also failed to see any star in the position of the one given by Smyth in the Bedford Catalogue, but noticed a minute star having a position angle of 170° or 175° at a distance of 75″. This star is the same as the one mentioned by Mr. Webb. I find, on referring to Smyth's diagram of this object in the MSS. of the Bedford Catalogue, that the position angle is undoubtedly about 170°. As he only credited his measures with a weight of 1—a weight which, by his own admission, represents nearly worthlessness—the apparent alteration in the distance may be easily explained. Smyth's magnitudes are so exceedingly vague and inaccurate that no suspicion of variability can be entertained for a moment. Sm. gives the distance of the companion to the next star but one in the *Cycle* (63 *Geminorum*; *Cycle*, No. 288) as 50″. H$_{\odot}$, in 1783, gave 44″·25; Main, in 1863, 44″·61. Mistakes of this kind, however, occur so frequently in the Bedford Catalogue as to be hardly worth noticing in detail.

β Canis Minoris. Cycle, No. 289.

	A-B °	A-B "	A-C °	A-C "	
Sm.	80·0	35·0	312·0	105·0	1831·8
Bu.	73·2	120±	311·2	141·8	1877·1

Burnham observes of the discrepancies between the published distances of these companions and of the comes of *β Canis Majoris* and his own measures: "Of course any such change since Smyth's observations is out of the question."

45 H$_{\odot}$ IV. *Geminorum. Cycle*, No. 290.

	°		
*H$_{2}$.	355		1833
Sm.	355·0	95·0	1836·2
OΣ.	2·38	100·12	1853·2
Kn.	2·44	100·16	1864·9

OΣ remarks (*Mélanges* etc., iii., p. 572): "La direction 85° *n.p.*, estimée par Sir John Herschel, est erronée. Probablement il faut lire *n.f.* au lieu de *n.p.* Cependant il est bien curieux que la même erreur soit commise par l'amiral Smyth dans son Bedford Catalogue."

α Canis Minoris. Cycle, No. 298.

	°	″	s		
Sm.	85·0	145·0 (MSS. Δ R.A. 18·3)		1833·81	B 8m.

This is the celebrated missing star near *Procyon*. A moment's inspection will show that the two distances given by Smyth are irreconcilable the one with the other. Taking the proper motion of *Procyon* into account, the estimate Δ R.A. = 18s·3 will accord fairly well with the actual distance of a small star of about the 9th magnitude, which has been found to be a close pair by Bird, and independently detected to be such by Burnham and Dembowski. The following are some of the measures:—

	°	″	″	
Se.	83·60	331·62 (misprinted 33·162)		1856·16
Morton.	83·89	327·6		1857·92
Powell.	83·1	332·2		1860·82
Flammarion.	80·5	346·5		1877·17

175 P. VII. *Argus. Cycle*, No. 301.

	°	″	
*Piazzi. (reduced)	325·0	10·5	1800·0
Sm.	326·8	9·8	1831·9

Smyth's position angle is quite erroneous. Ja. gives 318°·8 (1846·2).

δ *Cancri. Cycle*, No. 335.

		″	
*H_2.	160	25	II Cat.
Sm.	163·0	25·0	1838·2
Lamont.	123·8	27·94	1836·2
Bu.	113·9	40·97	1878·2

Cf. "*Observatory*," No. 14. Smyth has copied Herschel's fallacious measure.

78 Ḥ 1. *Ursæ Majoris. Cycle*, No. 365.

Sm. R.A. 9h 34m 52s, 1840·0. D'Arrest, in his *Sid. Neb. Obs. Hav.*, points out that Herschel's R.A. of this nebula is 1m too little. Smyth, though he professes to have determined its place independently, has fallen into the same error. Taking D'Arrest's R.A. as correct, Smyth's should be 9h 35m 47s, 1840·0.

ψ *Leonis. Cycle*, No. 366.

ψ *Leonis* is not variable, as stated in the Bedford Catalogue. It is probably confused with R *Leonis*, the place of which for 1840·0 is $9^h\ 38^m\ 57^s + 12°\ 10'·0$.

γ *Leonis. Cycle*, No. 376.

M. Flammarion remarks (*Catalogue des Étoiles doubles et multiples etc.*, p. 59): "Il y a encore un autre point douteux. Sm. qui a mesuré tant de compagnons éloignés, n'a pas mesuré celui-ci [viz. C at 292°·8 : 229″·3 : 1877], quoiqu'il ait mesuré cinq fois γ de 1831 à 1843, et il a écrit: 'There are two stars in a line with A in the *n.p.* quadrant.' C'est évidemment l'une de ces étoiles. Il y en a une autre, D, de huitième grandeur, plus éloignée que C, et formant avec elle angle de 328° ± à une distance d'environ le tiers de AC, et une autre, E, de dixième grandeur plus loin encore, à un distance un peu plus grande que celle de CD, et un peu plus au nord: elles sont presque sur une même ligne avec C, mais D n'est pas du tout sur la même ligne que C relativement à A, et pour quelle s'y soit trouvée il y a 40 ans, il faut que le déplacement ait été plus grand que celui de γ." On referring to the diagram of this object in the MSS., I find that C and D are by no means in the same line with A. Many of the descriptions of such objects in the text of the Bedford Catalogue are deplorably inexact, and no reliance whatever can be placed in them.

β *Leonis. Cycle*, No. 425.

	°	″	
Sm.	114·0	298·0	1833·5

Smyth's position angle should be increased by 90°. It is not at all probable, as Burnham has remarked, that the small star seen by Kn. is Smyth's, and is therefore a variable.

62 Ḥ IV. *Ursæ Majoris. Cycle*, No. 452.

	h	m	s	
Sm.	RA. 11	47	3	1840·0

Herschel's R.A. is, according to D'Arrest, 1^m too small. Smyth states that "its mean apparent place was obtained by differentiation from that of γ *Ursæ Majoris*." It is remarkable, therefore, that his R.A. is also 1^m behind the correct one. It should be $11^h\ 48^m\ 6^s$, 1840·0.

53 *Virginis. Cycle*, No. 472.

	°	″		
*H_x.	30·0 ±	50	V. Cat.	"Position by diagram."
Sm.	35 0	45·0	1833·4	
Bu.	9·3	70·56	1878·2	

61 *Virginis*. *Cycle*, No. 477.

	°	″	
*Hj.	345·0	73·25	1783·0
Sm.	340·6	Δ R.A. 2ˢ·8	1832·3
Kn.	22·6	169·29	1862·3
Bu.	25·2	189·34	1878·3

Smyth's observation is incomprehensible on the assumption that he really examined the star.

10 [54] *Hydræ*. *Cycle*, No. 519.

	°	″	
Hj.	128·2	11·29	1783·9
*H. & S.	136·7	9 95	1822·9
Sm.	138·4	9·8	1831·5
Howe.	129·8	9·68	1876·4

Smyth says that the measures of H. and S. show "a considerable direct motion in the elapsed time, which my measures appear to substantiate."

212 P. XIV. *Libræ*. *Cycle*, No. 524.

	A-B °	″			B-C °	″	
S. & H.	270·1	10·82	1823·3	*H_2	321·5	20·0	V. Cat.
Sm.	272·6	10·3	1833·4				
					A-C		
Ja.	284·0	13·34	1856·4	Sm.	320·0	20·0	1833 4
Bu.	290·8	15·30	1878·3	Bu.	322·2	120·6	1878·3

H_2 gives the position of B–C correctly. Smyth has overlooked the fact that Herschel measured B–C, and has given almost the same measures for A–C. There is no misprint in the Bedford Catalogue, as the diagram of the object in the MSS. agrees exactly with the *Cycle*. (*Cf. English Mechanic*, Nos. 687 and 690, May 24 and June 14, 1878.)

[illegible] *Libræ*. *Cycle*, No. 532.

Hj.	59·05	1781·4
*H. & S.	50·63	1822·8
Sm.	51·3	1837·4
Bu.	57·5	1878·4

Here Smyth has followed Herschel and South's erroneous [illegible]

764 ♄ II. *Draconis. Cycle*, No. 550.

Sm. R.A. $15^h\ 35^m\ 53^s$, 1840·0. Using D'Arrest's correction, this should be $15^h\ 35^m\ 25^s$. The R.A. of Herschel II. is also in error.

39 *Serpentis. Cycle*, No. 554.

	°	″	
Sm.	355 0	12·0	1835·57

Herschel II. says of this object (*Memoirs*, vol. xl., p. 139): "This star, 39 *Serpentis*, is described by Smyth as identical with ♄ III. 25; but it is ♄ III. 25 [45 in original, but evidently 25] described by ♄ as 39 *Serpentarii*, not *Serpentis*, and is accordingly set down in *h's* synopsis of ♄*h.* as 39 *Ophiuchi* (another name of *Serpentarius*) to avoid the equivoque of the abbreviation *Serp.*, and is in R.A. 17^h, N.P.D. 114°. It is remarkable, however, that the measures given by ♄ and by Smyth agree both in position and distance, and both agree with those of 36 *Ophiuchi* (which see).—J. H." Smyth says of 39 *Serpentis*: "This object is 25 ♄ III., and was thus registered by its discoverer. Pos. 357° 14′, Dist. 10″·0, Ep. 1780·65." Sm. gives for 36 *Ophiuchi* (*Cycle*, No. 607) 355°·6 : 11″·6 : 1830·63; 356°·2 : 12″·1 : 1838·52; and remarks: "It is 25 ♄ III., . . . and was thus micrometrically measured at Slough—Pos. 357°14′, Dist. 10″·03, 1782·46." 39 *Serpentis* has no companion, and it is abundantly evident that Smyth mistook Herschel's *Serp.* (i.e. *Serpentarii*) for *Serpentis*, and has *measured*, therefore, a companion which has no existence, and moreover was careful that his measures should agree with the supposed prior observation of ♄. It is noteworthy that these *measures* are stated to have been made in the year 1835, in which year he did not make any measure of 39 *Ophiuchi*. Smyth actually gives the colour of the star he did not observe!

136 P. XVI. *Herculis. Cycle*, No. 580.

Sm. R.A. $16^h\ 30^m\ 26^s$, 1840·0. It should be $16^h\ 31^m\ 26^s$, 1840·0, on the authority of the *Catalogus Generalis*.

μ^1 *Sagittarii. Cycle*, No 639.

	A-B °	′	A-C °	″	A-D °	″	
*H.	262·5	12	313·8	45	115·2	40	V. Cat.
Sm.	260·0	10·0	315·0	40·0	114·5	45·0	1835·6
Bu. 1878·4	259·2	16·9	312·9	48·6	115·4	50·5	Ja. 1847·3

185 and 186 P. XIX. *Antinoi. Cycle*, Nos. 702 and 703.

Cf. Dawes (*Memoirs*, vol. xxxv., pp. 494–496; *Notices*, vol. xxiii., pp. 34–37); Hunt (*Notices*, vol. xxxii., pp. 90, 91, &c.).

Smyth's position angles and distances are utterly inaccurate; and, to make matters worse, he has followed the erroneous results of Hl. Full explanations of the matter will be found in the papers cited above.

54 *Sagittarii. Cycle*, No. 705.

	A–B °	A–B ″	A–C °	A–C ′	
*H_2.	13·6	25 ±	273·0	15· ±	IV. Cat. (No. 1424)
Sm.	42·8	28·5	280·0	20 0	1837·58
Main.	41·4	45·90	caret.		1861·73
Bu.	41·7	45·57	244·5	35·76	1878·7

Herschel's 13°·6 is probably a misprint for 43°·6. A–B are first mentioned in Herschel's 2nd Catalogue, as H. 599, and the measures therein recorded are 6, 10 : 40° : 40″ : 1826·58. Smyth did not notice this, and so copied the error in Herschel's measure in Catalogue IV. Ja. gives for the distance of A–B 45″·6 in 1845·8. Smyth refers in the text to Herschel's observation of C in the IVth Catalogue (No. 1424), and has followed Herschel's inaccurate observations of that star also. Considerable mistakes in the position angles and distances of small stars are not uncommon in the Catalogues of the younger Herschel.

295 P. XIX. *Cygni. Cycle* 719.

This is *not* Kirch's variable, which is between χ (Flamsteed) and P XIX. 295. Sm. has followed Baily and Piazzi. (*Cf.* Stone in *Monthly Notices*, vol. xxvi., p. 273.)

2 P. XX. *Aquilæ. Cycle*, No. 733.

Sm. R.A. $20^h\ 1^m\ 51^s$, Dec. +16° 26′·8, 1840·0. Smyth's R.A. should be increased by 26^s, and his Decl. diminished by 7′·0.

σ^2 *Cygni. Cycle* No. 739.

	A–D °	A–D ′	A–D ″			A–B °	A–B ″	
*Σ. (as quoted by Sm.)	333	41·9	337·38	1835·95	*H_2.	332·8	20	H. 1945
Sm.	333·8		338·0	1838·67	Sm.	330·0	15·0	1838·67
Σ (*M. M.*, p. 270)	323	41·9	337·833	1835·95	Bu.	321·7	36·82	1878

Here Smyth *quotes* Struve's position angle as 333° 41′·9, with which his own position angle, credited with a weight of 9, agrees within the *tenth* of a degree. Herschel's distance of A–B is largely in error, and Smyth, as is usual, has followed him. The Bedford MSS. give 333°·8 for A–D, so that there is no misprint.

178 P. XX. *Delphini. Cycle*, No. 751.

	A-C °	″	
*H_2.	121·5	20 0	IV. Cat.
Sm.	125·0	20·0	1835·91
Bu.	108·4	23·4	1878·2

β Delphini. Cycle, No. 756.

	A-C °	″	
*H_2.	107·7	18·0	V. Cat.
Sm.	105·5	15·0	1834·79
Lamont.	112·8	33·1	1836·8
Bu.	115·7	27·4	1878·6

Lamont gives 202° 49′·5, which I have diminished by 90°. Bu. has found A to be a close double.

α Cygni. Cycle, No. 760.

	°	″	
Ll.	90·0 ±	60·0 ±	1790·69
*H_2.	104·1	Δ R.A. 7ˢ·3	IV. Cat.
Sm.	102·5	108·5	1837·65
Bond I.	88 3	95·5	1848

β Equulei. Cycle, No. 784.

	A-B °	″	B-b °	″	A-C °	″	
*H_2.	314·4	40·0	14·5	2·0	278·0	50·0	V. Cat.
Sm.	317·0	35·0	15·0	3·0	275·0	50·0	1836 68
Bu.	308·7	67·4	10·4	6·0	275·9	86·3	1878·6

β Aquarii. Cycle, No. 786.

	A-B °	″	
*H_2.	322·8	20·0	IV. Cat.
Sm.	320·0	25·0	1833·73
Bu.	320·0	34·25	1877·7

20 *Pegasi. Cycle*, No. 799.

	A-B °	″	
*H_2.	320·0	40	II., I. Cat.
Sm.	330·0	35·0	1838·66
Bu.	326·1	51·3	1877·7

Alternative Measures of Distance from the MSS.

	Δ R.A. s		Δ R.A. s		Δ R.A. s
β Cassiopeiæ	19·1	α Orionis	6·8	α Canis Minoris	18·3
α Andromedæ	4·57	μ Geminor.	5·4	α Boötis	15·1
14 Arietis, A–C	3·8	β Can. Maj.	4·7	δ Boötis	7·9
o Ceti	7·8	ζ Gem., A–B	1·8	δ Aquilæ	6·6
δ Persei	7·0	,, A–C	5·0	α Cephei	9·8 (w_1)
257 P. IV. Tauri, A–C	4·3	δ Can. Maj.	13·5	,,	8·8 (w_2)
γ Orionis	3·6	30 Can. Maj.	5·6	4 Cassiop., A–C	25·3
β Leporis	13·1	η Can. Maj.	13·4	,, A–B	7·4
ε Orionis	9·8	63 Geminor.	1·8	γ Cephei, about	44
124 Tauri, A–B	5·5	145 P. VII. Argûs	1·5	171 P. XXIII. Androm., A–C	8·4
,, A–D	1·0				

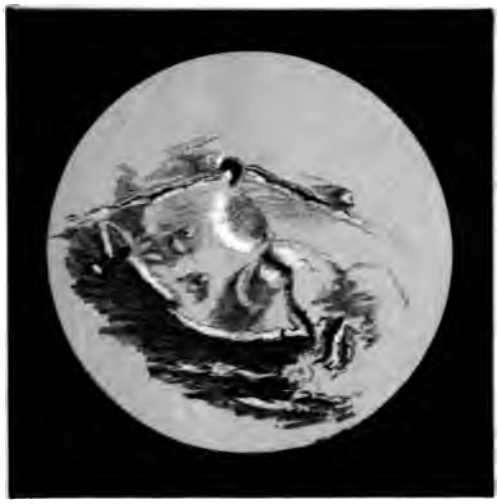
ERRATA (from the List issued by Admiral Smyth).

"A rigorous re-examination of Captain Smyth's *Cycle of Celestial Objects* has led to the detection of the following typographical errors. These the Amateur-Astronomer is earnestly requested to correct in his copy with a pen, in order that they may occasion no loss of time to him.

VOLUME II.

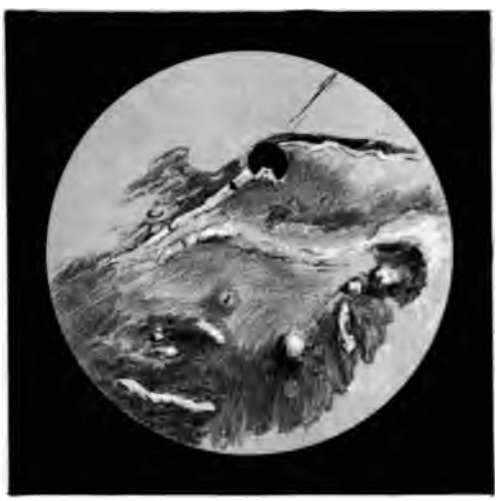
Page 25, No. xxxix., *for* R.A. $0^h\ 57^m\ 23^s$ *read* $0^h\ 57^m\ 39^s$.
,, 33, No. xlix., *for* Dec. 57° 56′·9, *read* 57° 28′·9.
,, 34, No. l., l. 4, *for* Epoch 1830·39, *read* 1830·89.
,, 46, No. lxxiv., *for* Dec. 37° 27′·9, *read* 36° 27′·9.
,, 54, No. lxxxvii., *for* R.A. $2^h\ 1^m\ 16^s$, *read* $2^h\ 1^m\ 12^s$.
,, 67, No. cix., *for* R.A. $2^h\ 33^m\ 8^s$, *read* $2^h\ 33^m\ 18^s$.
,, 94, No. cliii., *for* R.A. $3^h\ 59^m\ 6^s$, *read* $3^h\ 59^m\ 11^s$.
,, 115, No. clxxxviii., *for* Dist. of AC = 15″·1, *read* 15″·0.
,, 152, No. ccli., *for* R.A. $6^h\ 22^m\ 45^s$, *read* $6^h\ 22^m\ 25^s$.
,, 199, No. ccccxxix., *for* R.A. $8^h\ 30^m\ 31^s$, *read* $8^h\ 30^m\ 41^s$.
,, 227, No. ccclxxiv., *for* Mean N.P.D. (l. 5) $77^h\ 15^m\ 12^s{\cdot}43$, *read* 77° 15′ 12″·43.
,, 256, No. ccccxxii., *for* Leo, l. i. of Description, *read* Ursa.
,, 289, No. ccccIxviii., *for* R.A. $12^h\ 51^m\ 30^s$, *read* $12^h\ 51^m\ 26^s$.
,, 300, No. ccccIxxxi., *for* μ Hydræ, *read* u.
,, 335, No. dxxxiii., *for* 22 M., *read* 102 M.
,, 371, No. dlxxxv., l. 2, *for* 15^h, *read* 16^h.
,, 392, No. dcxvii., *for* Σ's ∠ 76° 77′, l. 32, *read* 76°·77.
,, 411, No. dcxxxvii., *for* ∠ in 1842·39 = 255°·0, *read* 259°·5.
,, 442, No. dclxxxii., *for* Dec. 35° 15′·2, *read* 32° 15′·2.
,, 453, No. dccvi., *for* 51 Ḥ V. *read* 51 Ḥ IV.
,, 454, No. dccx., *for* 36 Ḥ V., l. 2, *ab imo, read* 46 Ḥ V.
,, 534, No. dcccxxxviii., *for* Dec. 64° 24′·3, *read* 61° 24′·3.'

I.

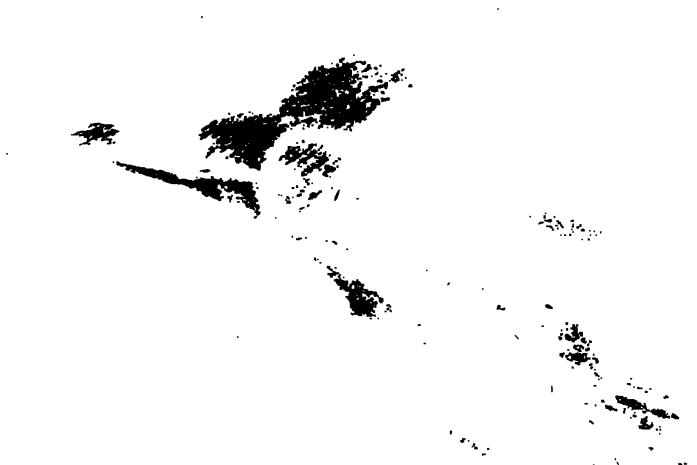


1878, Oct. 17, 12h. 20m., G.M.T.

II.



1878, Oct. 17, 13h. 40m., G.M.T.



1878, Dec. 10, 12h., G.M.T., powers 307 & 442.

W.H. Maltby & Sons, Imp.

Postscript.

I have received the two following measures by letter from Mr. Burnham, too late for insertion in the body of my paper.

β Andromedæ. Cycle, No. 43.

	A-B °	A-B "	
Sm.	299·0	225·0	1839·5
Bu.	293·6	297·9	1878·9 (single distance)

δ Persei. Cycle, No. 135.

	A-B °	A-B "	
Sm.	315·0	140·0	1833·7
Bu.	313·3	108·62	1878·9

I do not know of any other measures. Mr. Burnham's are made with the magnificent Dearborn refractor of 18½ inches aperture.

Clapham,
1878, *December* 18.

Note on some hitherto Unnoticed Features near the Lunar Crater Hyginus. By Lord Lindsay and Dr. R. Copeland.

It may be as well to preface the following note by the statement that it is not the intention of the writers to prove or disprove the existence of active volcanic agency in the Moon at the present moment. The sole object in view is to place on record certain not uninteresting observations confirming the well-known fact that the neighbourhood of the lunar crater *Hyginus* is full of complicated shallow irregularities and strongly marked differences of tone, which tend together to produce great apparent changes of surface configuration with change of illumination, and further to show that there exist striking features in the immediate neighbourhood which have hitherto escaped clear detection, but of which some traces may be found in the comparatively old map of Lohrmann.

During the night of October 17, 1878, the terminator passed over *Hyginus*. The whole night was fine, and the definition good, at times exceptionally so.

Under these circumstances the configurations of the region adjoining Schröter's well-known Rille were revealed in a very full degree. Six drawings were made between $12^h\ 20^m$ and 17^h G.M.T. Reserving for a future occasion a fuller discussion (based on micrometrical measures) of all these sketches, special attention is drawn to Nos. I, III, V, and VI.

Sketch No. I, which is a general representation of everything that is visible near *Hyginus*, exhibits no trace of a crater to the S.W. of *Hyginus*; but in No III, taken at $15^h\ 15^m$, a crescent-shaped ridge is shown abutting on that side of the crater.

At this time the observers were unable to interpret the meaning of this curved ridge; but by $16^h\ 15^m$, Sketch No. V,* it had become obvious enough that the ridge formed part of the wall of a shallow but very regular crater, which may be called No. 29 (*see* key map), immediately S.W. of *Hyginus*. In the same direction there was also a second, somewhat smaller, though most obvious crater.

These two craters seem never to have been previously observed. The south-westernmost of them must have disappeared in the shadow of night almost immediately after it was first seen; for a sketch made at 17^h (No. VI) shows no trace of it. The written observations also expressly confirm this fact.

On the other hand, its larger neighbour had become the most conspicuous object in the whole district: *Hyginus* being merged into the darkness of a large shallow depression to the N.E. that had been gradually making itself more and more obvious during the course of the night. On November 4, 1878, the region was examined under a moderately high illumination. It was then seen that the western end of a dark patch S. of *Hyginus* formed, and was coterminal towards the west with, the floor of No. 29; and, indeed, on November 8, one of us, in conjunction with Mr. G. J. Lohse, the Assistant Astronomer, saw most clearly that the western end of the above-mentioned shading was almost entirely, or perhaps completely, separated by a sort of strait from the main portion of the marking. This feature was again most clearly seen on December 10, at midnight. (Outline sketch).

This shaded patch seems to be visible under all except the very lowest illuminations, and is sufficiently well shown in Lohrmann, Sec. I., to convince us that it has, not greatly changed since his day. It is therefore highly improbable that Crater No. 29 has been formed since the date of Lohrmann's observations.† Yet the shading is not given by Schmidt or in the *Mappa Selenographica*. Possibly it may be shown in the large-scale map of this region by Mädler, which we have not had an opportunity of examining. It is given, however, in Dr Klein's Map, in *Sirius*, No. 8, 1878, but of a shape differing considerably from that in which we see it—Sketches of November 4 and December 10.

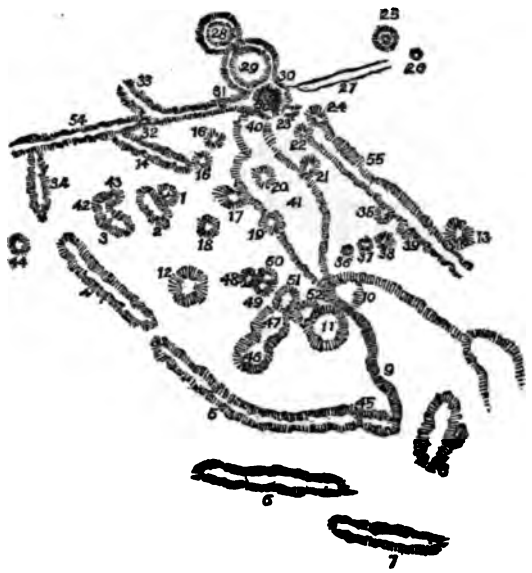
These facts show with what extreme caution all presumed evidence of change on the Moon's surface ought to be received, and how necessary it is to accumulate observations made under various, and particularly *low*, illuminations.

The observations were made with powers 307 and 442, on a refractor of 15·06 inches aperture.

Dun Echt Observatory,
1878, *Dec.* 11.

* Note to Sketch V. Finished about $16^h\ 20^m$ G.M.T., at which time the shallow crater No. 29 was as black as *Hyginus*, and the peak No. 20 had disappeared.

† The *Topographie der sichtbaren Mondoberflächen*, Abt. I., containing Sections I.-IV., was published in 1824.



Description.

Reference No. to Key-map.	No. of Sketch in which the object is shown.						Remarks.
1	I	II	III	IV	V	VI	Seen as a crater in 1, 2, and 3.
2	I	II					
3	I	II					
4	I	II					
5–8	I						
9	I	II			V	VI	A deep valley.
10	I	II			V	VI	
11	I	II			V	VI	
12	I	II			V	VI	
13	I	II					And probably in V and VI.
14			III				A very low ridge.
15			III	IV	V		A small hill.
16			III	IV			A very low hill.
17			III	IV	V		A hill.
18			III		V		A low hill.
19			III	IV			A rise in edge of depression.
20		II	III	IV	V		A hill in a depression.
21			III	IV	V	VI	A hill on table-land.
22					V	VI	Elevation on edge of Rille.
23					V	VI	„ „ „

11, 52, 51, 47, and 46 are portions of Mädler's *Hyginus β*.
25 is Mädler's *Hyginus b*.
The Rille, 27, was discovered by Lohrmann.

Note on a Phenomenon seen in the occultation of a Star at the Moon's bright limb. By W. H. M. Christie, Esq.

At the disappearance of 17 *Tauri* at the Moon's bright limb, on November 10, 1878, a curious phenomenon was presented, which appears to throw some light on the apparent projection of a star on the Moon. I observed the occultation, under favourable atmospheric conditions, with the full aperture (nearly 13 inches) of the Great Equatoreal of the Royal Observatory, Greenwich, using a negative eyepiece with a power of 310, and my eye was much dazzled by the intense light of the Moon, only 19^h past the full.

The star is of 4 magnitude, and as it appeared to approach the Moon's limb, I fixed my attention on it, being afraid of losing it in the overpowering light of the Moon. I watched it steadily till it came up to the line of the limb, expecting it to disappear at a slight notch in the limb; but instead of that, the Moon's limb, to my surprise, seemed to recede for some 3 or 4 seconds of time, and the star disappeared gradually in a sort of luminous haze, through which it was seen with more and more difficulty as it advanced. At the instant of disappearance the star was seen apparently perfectly bisected by the limb, if limb it could be called, that is, completely shorn of its rays and half the disk on the one side (towards the Moon), and intact on the other.

This observation appears to accord perfectly with the explanation of the phenomenon of projection which the Astronomer Royal has given in vol. xxviii. of the *Memoirs*. The star was not bright enough to be seen distinctly projected on the Moon's disk, but was yet not so faint as to be overpowered by the irradiation at the limb. A spurious limb being formed, as the Astronomer Royal has explained, by the superposition of diffraction images, the intensity of light would increase gradually from the spurious to the true limb. At the former the star's light overpowered that of the Moon; at the latter the Moon's light overpowered that of the star. The circumstance that the diffraction image of the star (disk and rays) was cut off completely on the side of the Moon at the instant of disappearance is in perfect accordance with the Astronomer Royal's explanation.

At the disappearance of 20 *Tauri*, a star of 5 magnitude, I tried the effect of a graduated dark wedge (neutral tint) to diminish the glare of the Moon, and was enabled to observe the occultation perfectly. The star disappeared when in apparent contact with the bright limb, but not instantaneously, as in occultations at the dark limb. At the occultation of 16 *Tauri*, a star of 6·7 magnitude, the star was lost in the glare of the Moon before coming up to the limb.

Royal Observatory, Greenwich,
1878, *December* 9.

On a New Variable Star, ι Andromedæ. By J. E. Gore, Esq.

From my own observations during the last three and a half years I am confident that this star is variable to the extent of about half a magnitude. It is sometimes distinctly *brighter* than κ *Andromedæ*, and sometimes quite as distinctly *fainter*. The star has been estimated 4· mag., by most of the authorities, but it was rated as low as 7 mag. by Bradley and Piazzi, and it is 6 mag. in Harding's *Atlas*. D'Agelet rated it once 3–4 mag., and once 7 mag. Heis gives ι 4 mag. and κ 4–5 mag. The following are my observations :—

May 1875.	ι very slightly fainter than κ *Andromedæ*.
Aug 1875.	Same relative brilliancy.
Jan. 30, 1876.	Very slightly brighter than κ.
Oct. 1876.	A little less than κ (about ¼ mag.)
Dec. 13, 1876.	ι slightly brighter than κ.
Feb. 10, 1877.	ι slightly but distinctly brighter than κ *Andromedæ*.
Feb. 16, 1877.	ι and κ almost exactly equal.
Aug. 4, 1877.	ι very slightly less than κ.
Aug. 23, 1877.	ι almost exactly equal to κ—during totality of lunar eclipse.
Aug. 31, 1877.	ι slightly, but decidedly, less than κ.
Oct. 30, 1878.	ι only just perceptibly less than κ.

I have not been able to determine the period, but it would seem to be tolerably short.

Dromard, Co. Sligo,
November 19, 1878.

On a Variable Diaphragm for use in Solar and Sidereal Observations. By F. W. Levander, Esq.

The instrument which I have the honour to bring to the notice of the Society had its origin in a desire on my part to devise a plan which should possess most, if not all, of the advantages of a Dawes' eye-piece, but capable of being produced at a smaller cost. It consists of an adapter to slide into the tube, as an ordinary eye-piece, and of a draw-tube to receive any eye-piece; between these there is a diaphragm, which, by one motion of the milled screw, is capable of being opened to the greatest extent required, or of being entirely closed. For solar work a draw-tube slides in such a manner that the interchangeable dark glasses with which it is furnished are at some distance within the focus of the object-glass. To prevent time being lost during an observation by interchanging these, it was proposed to adopt a revolving disk of dark glasses, as in Dawes' instrument; but the use, which has been kindly suggested, of a neutral tint wedge is,

I think, the best plan. By these means the light can be diminished to any extent, and with the diaphragm any part of the solar disk can be isolated and examined.

The instrument will also be found to be of great use in examining or detecting faint points of light when near brighter objects, as double stars of very diverse magnitudes, faint satellites of planets, lunar formations, &c., by reducing the glare of the surroundings and obviating the inconvenience of using the edge of the object-glass or speculum or the introduction of a field-bar. It also serves for measuring the vanishing point of stars, for testing magnitudes.

The screw-head is divided into equal parts, and, by noticing the reading when a particular observation was made, it may be recovered—under similar atmospheric conditions—at a future time. By a simple arrangement, the diaphragm may be placed out of the centre, so that, by revolving the instrument, the space round an object in the centre of the field of view may be examined.

I have to thank Messrs. Horne & Thornthwaite for the care with which they have carried out my design.

7 *Chalcot Crescent, Regent's Park, N.W.,*
December 11, 1878.

Explanation by Captain Bigg-Wither in regard to his Observation of the Transit of Venus, see *Monthly Notices*, Vol. xxxviii., foot-note, p. 433.

The longitude ($4^h\ 48^m\ 1^s{\cdot}8$ E.) given for Mooltan was not taken from the survey, but was the most probable mean of the results of 15 occultations of stars by the Moon; so that the correction of $+2^s{\cdot}3$ made by Captain Tupman is inadmissible. The local time for all these observations, as well as for the Transit of *Venus*, was obtained by a 24-inch transit instrument and a sidereal chronometer, and was in every case known certainly within half a second of the truth. The occultations were observed with the same telescope as that used for the Transit of *Venus*, and were all taken from the "Elements" in the *Nautical Almanac*; they were reduced, using the Moon's tabular places as given in the *Nautical Almanac*.

Mooltan,
December 9, 1878.

Errata.

P. 37, line *a*, col. E of Table II., *insert* 581.

" " " 3 " III., *for* ·1 *read* ·15.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXIX. *February* 14, 1879. No. 4.

Lord LINDSAY, M.P., F.R.S., President, in the Chair.

John Marshall, Esq., Albion Place, Leeds; and
R. Palmer Thomas, Esq., 13 North Villas, Camden Square, N.W.;

were balloted for and duly elected Fellows of the Society.

REPORT OF THE COUNCIL TO THE FIFTY-NINTH ANNUAL GENERAL MEETING OF THE SOCIETY.

Progress and present state of the Society:—

	Compounders	Annual Subscribers	Non-resident	Mathematical Society	Patroness	Total Fellows	Associates	Grand Total
December 31, 1877	218	351	4	6	1	580	37	617
Since elected ...	+3	+29	...	...	...	...	+4	...
Deceased	−6	−10	...	...	...	...	−1	...
Removals	+3	−3	...	...	...	...	...	...
Resigned	...	−5	...	...	...	...	...	...
December 31, 1878	218	362	4	6	1	591	40	631

Mr. Barrow's Account as Treasurer of the Royal

RECEIPTS.

	£ s. d.	£ s. d.
Balance at Bankers' Dec. 31, 1877, as per Bankers' book... ... £240 19 9		
Less amount of outstanding cheque 15 0 0		
	225 19 9	
„ in hand of Secretary of Library Committee:		
On account of Turnor Fund	1 6 11	
On account of Library Expenses ...	20 8 6	
„ in hand on Petty Cash account	13 11 7	
		261 6 9
Dividend on £6,400 Consols	94 16 0	
„ £5,700 New 3 per cent. Stock ...	84 8 8	
„ £6,400 Consols	94 0 0	
„ £5,700 New 3 per cent. Stock ...	83 14 5	
		356 19 1
Received on account of Subscriptions:		
Arrears of Contributions	201 16 0	
255 Contributions for 1878	535 10 0	
2 Contributions for 1879	4 4 0	
33 Admission Fees	69 6 0	
29 First Contributions	48 6 0	
		859 2 0
7 Composition Fees		147 0 0
Sales of Publications:—		
At Society's Rooms during 1878	169 11 10	
At Williams & Norgate's during 1877 ...	12 7 6	
		181 19 4
Received from the Government Fund of the Royal Society on account of Mr. Gill's Expedition to Ascension		250 0 0
		£2,056 7 2

Astronomical Society, from Dec. 31, 1877, to Dec. 31, 1878.

EXPENDITURE.

	£	s.	d.	£.	s.	d.
Salaries:—						
Editor of *Monthly Notices*	60	0	0			
Assistant Secretary	150	0	0			
				210	0	0
Income Tax and House Duty				6	11	3
Fire Insurance				7	16	6
Printing and Lithography:—						
Spottiswoode & Co.	438	10	6			
Hazell, Watson, & Viney	206	13	0			
M. and N. Hanhart	15	12	0			
				660	15	6
Turnor Fund: Books purchased during year ...	75	5	0			
Library expenses: Binding	108	15	10			
Cards for Library Catalogue	8	13	4			
				192	14	2
Purchase of scarce volumes of the *Monthly Notices*				5	0	0
House expenses	29	9	8			
Wages	23	11	0			
Stamps and postage	60	10	7			
Carriage of books and parcels	6	19	9			
Stationery and office expenses	10	18	8			
Expenses of meetings	20	0	0			
Coals and gas	48	0	7			
Fittings in lavatory	19	8	0			
Sundry fittings and repairs	9	1	5			
Sundries	6	7	5			
Cheque book	0	8	4			
Bankers' commission on cheques	0	1	11			
				234	17	4
Paid on account of Mr. Gill's Expedition to Ascension (previous payment of £400. 15*s.* 6*d.* appears in last year's account. Total amount of grant £500)				99	4	6
Mrs. Jackson-Gwilt's annuity				8	19	0
Balance at Bankers' Dec. 31, 1878	605	0	3			
,, in hand of Secretary of Library Committee:						
On account of Turnor Fund	1	1	11			
On account of Library expenses ...	16	12	8			
,, in hand on Petty Cash account	7	14	1			
				630	8	11
				£2,056	7	2

Examined and found correct, J. Kennedy Esdaile.
A. A. Common.
Wentworth Erck.

Assets and present Property of the Society, January 1, 1879:—

	£	s.	d.	£	s.	d.
Balance at Bankers' Dec. 31, 1878	605	0	3			
„ in hand of Secretary of Library Committee on account of Turnor Fund	1	1	11			
„ ditto ditto on account of Library expenses	16	12	8			
„ in hand on Petty Cash account	7	14	1			
				630	8	11
Due on account of Subscriptions:—						
4 Contributions of 5 years' standing ...	42	0	0			
7 „ 4 „ ...	58	16	0			
11 „ 3 „ ...	69	6	0			
21 „ 2 „ ...	88	4	0			
47 „ 1 „ ...	98	14	0			
Various amounts	12	12	0			
Two admission fees and first contributions	6	6	0			
	375	18	0			
Less two contributions paid in advance ...	4	4	0			
				371	14	0
Due for publications	1	0	0			
„ from Williams & Norgate for sales during 1878	36	17	9			
				37	17	9

£6,400 Consols, including the Lee Fund (£300), the Turnor Fund (£450), and the Horrox Memorial Fund (£100).

£5,700 New 3 per cent. Stock, including Mrs. Jackson-Gwilt's gift (£300).

Astronomical and other MSS., books, prints, &c.

One gold medal.

Unsold publications of the Society &c.

Report of the Auditors.

We, the duly appointed Auditors, beg to lay before this General Meeting of the Royal Astronomical Society the following Report:—

1. We have examined the Treasurer's account, and an account of the assets and property of the Society, and have found and certified the same to be correct.

2. The receipts and expenditure for the past year are as stated in the Treasurer's account.

3. The cash in hand on December 31, 1878, including the balance at the Bankers', amounts to 630*l.* 8*s.* 11*d.*

4. The funded property of the Society is in a satisfactory state, and the books, instruments, and other effects have been examined as far as possible and found in a satisfactory condition.

5. We have laid on the table a list of the names of those Fellows who are now in arrear for sums due at the last Annual General Meeting, with the amount due against each Fellow's name.

J. KENNEDY ESDAILE.
A. A. COMMON.
WENTWORTH ERCK.

Stock in hand of volumes of the *Monthly Notices*:—

Vol.	At Society's Rooms.	At Williams & Norgate's.	Vol.	At Society's Rooms.	At Williams & Norgate's.
I.	83	1	XXI.	24	...
II.	84	...	XXII.	39	...
III.	...	...	XXIII.	22	...
IV.	...	...	XXIV.	25	...
V.	...	...	XXV.	7	...
VI.	50	...	XXVI.	13	...
VII.	2	...	XXVII.	2	...
VIII.	143	2	XXVIII.	79	2
IX.	25	3	XXIX.	60	1
X.	178	2	XXX.	74	4
XI.	186	2	XXXI.	107	2
XII.	12	2	XXXII.	134	2
XIII.	164	3	XXXIII.	120	4
XIV.	110	3	XXXIV.	95	7
XV.	130	2	XXXV.	79	5
XVI.	112	3	XXXVI.	45	1
XVII.	138	1	XXXVII.	59	5
XVIII.	172	...	XXXVIII.	125	14
XIX.	68	...	Index to *Monthly Notices*	607	...
XX.	40	...			

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI., XXXVII., and XXXVIII., no complete volumes can be formed from the separate numbers in stock.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms.	At Williams & Norgate's.	Vol.	At Society's Rooms.	At Williams & Norgate's.
I. Part 1	5	...	XXII.	163	1
I. Part 2	45	..	XXIII.	159	1
II. Part 1	61	...	XXIV.	165	2
II. Part 2	23	...	XXV.	177	2
III. Part 1	70	...	XXVI.	181	2
III. Part 2	92	...	XXVII.	434	1
IV. Part 1	86	3	XXVIII.	396	1
IV. Part 2	97	3	XXIX.	421	1
V.	111	4	XXX.	172	1
VI.	131	4	XXXI.	157	1
VII.	155	3	XXXII.	174	1
VIII.	133	4	XXXIII.	178	3
IX.	142	3	XXXIV.	177	9
X.	153	1	XXXV.	127	3
XI.	165	1	XXXVI. (with M.N.)	206	15
XII.	169	...	XXXVI. (without)	16	...
XIII.	177	...	XXXVII. Part 1	372	8
XIV.	378	3	XXXVII. Part 2	320	6
XV.	149	1	XXXVIII.	313	1
XVI.	179	...	XXXIX. Part 1	291	1
XVII.	155	3	XXXIX. Part 2	308	2
XVIII.	159	...	XL.	336	1
XIX.	164	...	XLII.	321	2
XX.	162	2	XLIII.	380	3
XXI. Part 1	314	...	Index to *Memoirs*	674	4
XXI. Part 2	99	...			
XXI. 1 & 2 (together)	68	2			

Instruments belonging to the Society.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.
„ 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.

No. 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Ultzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatoreal.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian Telescope (late Mr. Shearman's).
„ 10. The Variation transit instrument (late Mr. Shearman's).
„ 12. The *Fuller* theodolite.
„ 13. The Standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatoreal.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatoreal, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A quadrant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the Precession of the Equinoxes. The *Sheepshanks* collection:—
„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.
„ 29. (3) $4\frac{8}{10}$-inch achromatic telescope, about 5 feet 6 inches focal length; finder; rack motion; double-image micrometer; two other micrometers; one terrestrial and ten astronomical eyepieces, applied by means of two adapters, with equatoreal stand, clock movement.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatoreal stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
„ 33. (7) 2-foot navy telescope.
„ 34. (8) A transit instrument of 45 inches focal length; with iron stand, and also Ys for fixing to stone piers; two axis levels.
„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.

No. 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

„ 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; a deal box with heavy stand for theodolite; a box containing the Y piece of level; two large and three small ground-glass bubbles divided; a box containing level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle, by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. The circle is divided on silver, and is read to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

No. 51. (25) Ordinary 4½-inch compass with needle.
„ 52. (26) Dipping needle, by Robinson.
„ 53. (27) Compass needle, mounted for variation.
„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
„ 55. (29) Box of magnetic apparatus.
„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.
„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
„ 58. (32) Plane 2⅜-inch speculum, artificial horizon, and stand.
„ 59. (33) 2½-inch circular level horizon, by Dollond.
„ 60. (34) Artificial horizon, roof, and trough; the trough 8¼ by 4¼ inches. Tripod stand.
„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square: one beam compass.
„ 62. (36) A pentagraph.
„ 63. (37) A noddy.
„ 64. (38) A small Galilean telescope with object-glass of rock crystal.
„ 65. (39) Five levels.
„ 66. (40) 18-inch celestial globe.
„ 67. (41) Varley stand for telescope.
„ 69. (43) Telescope, with the object-glass of rock crystal.
„ 70. Portable equatoreal stand.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. 9¼-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. A double image micrometer, by Troughton and Simms.

No. 86. A 4½-inch Gregorian Reflecting Telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.

„ 87. A 3¼-inch Gregorian Reflecting Telescope with wooden tripod stand.

„ 88. A pendulum with 5-foot brass suspension rod, working on knife edges, by Thomas Jones.

„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.

No. 90. An Arabic celestial globe of bronze, not quite 6 inches in diameter.

„ 91. An astronomical time watchcase, by Professor Chevallier.

„ 92. A 2-foot protractor, with two movable arms, and vernier.

„ 93. A beam compass, in box.

„ 94. A 2-foot navigation scale.

„ 95. Stand for testing measures of length. It consists of two T-shaped gun-metal bars 5½ feet long, to which are fitted two micrometers mounted with adjusting screws for level and position.

„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position angles.

„ 97. A 12-cell Leclanché battery.

Instruments Nos. 96 and 97 were purchased by Mr. Gill out of money contributed by the Society towards the expenses of his expedition to observe the opposition of *Mars*.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons:—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.

„ 12. The *Fuller* theodolite, to the Director of the Sydney Observatory.

„ 22. The *Matthew* equatoreal, to Mr. Brett.

„ 72. Two polarimeters, to Mr. Ranyard.

„ 74. Registering spectroscope, with prism, to Mr. Lecky.

„ 76. One 5-prism spectroscope, to Mr. Plummer.

„ 78. The 9¼-inch reflector, to Mr. Nelson.

From the *Sheepshanks* collection:—

No. 30. (4) 3¼-inch equatoreal and stand, to Mr. Sadler.

„ 31. (5) 2¾-inch telescope and stand, to Mr. Birt.

„ 34. (8) Transit instrument, to the Rev. Professor Pritchard.

„ 35. (9) Repeating theodolite, to the Sydney Observatory.

„ 39. (13) 8-inch repeating circle, to Mr. Plummer.

No. 42. (16) Mercury bottle, horizon and roof, to Captain Noble.
„ 43. (17) Hassler's reflecting circle, to Mr. Gill.
„ 69. (43) Telescope, with rock-crystal object-glass, to Dr. Huggins.

The Gold Medal.

The Council have awarded the Society's Gold Medal to Professor Asaph Hall for his discovery and observations of the satellites of *Mars*, and for his determination of their orbits. The President will lay before the Society the grounds upon which the Council have decided upon their award.

The Advowsons of Stone and Hartwell.

In the year 1836 Dr. John Lee, who was then Treasurer of the Royal Astronomical Society, executed a deed of gift by which he conveyed to the Society the advowson of Hartwell, and in 1844, by another deed of gift, he conveyed the advowson of Stone to the Society.

Shortly before the date of these deeds his estates had been resettled by Private Act of Parliament, by which the manors of Hartwell and Stone were entailed, leaving Dr. Lee with only a life interest in them. The living of Stone fell vacant in the lifetime of Dr. Lee, and the Society presented Dr. Booth, who held the living until last April, when he died. Soon after the death of Dr. Booth the Council received formal notice that the present lord of the manor of Hartwell, Mr. Edward Lee, intended to dispute the Society's title to both livings, on the ground that they were (in legal language) appendant to the manors, and consequently included in the entail.

The Council, nevertheless, presented the Rev. James Challis, M.A., of Trinity College, Cambridge, who, besides being the son of Professor Challis, a distinguished Fellow of the Society, had many other recommendations. Mr. Lee took steps to dispute the presentation, and the Council employed as their solicitor Mr. Merriman of Austin Friars, who has unusual opportunities of being acquainted with such matters. The result of Mr. Merriman's investigation was that he found that the advowson of Stone had long been severed from the manor, and that the Society's title was good; but that in the case of Hartwell the matter was at least very doubtful. The litigation to establish such a claim, depending on historical inquiries, would be very

costly; and, even if the Society succeeded, it would have to bear a great part of the costs, which could not, according to the rules laid down by the Courts, be recovered from the other side.

It was found that Mr. Lee did not want to present any friend of his own to the vacant living, and was willing to settle the dispute by purchasing, for the sum of £700, the advowson of Stone, subject to the Society's right of presentation to the existing vacancy, and to a release of the Society's claim to Hartwell being included.

The Council having been advised that the sum of £700 was a fair price under the circumstances, entered into a provisional agreement with Mr. Lee for the conveyance and release of all right and claim of the Society to the advowsons of Stone and Hartwell in consideration of the above-mentioned sum, and recommended that the Fellows of the Society should approve and concur in the proposed agreement.

The following resolution was therefore, at the instance of the Council, submitted to the Annual General Meeting held on the 14th of February 1879:—

> "That this Meeting approve and concur in a provisional agreement made between the Council and Mr. Edward Lee for the conveyance and release to Mr. Lee of all the right and claim of the Society to the advowsons of Stone and Hartwell in consideration of the sum of £700."

The Resolution, having been put by the President, was carried unanimously.

Mr. Gill's Expedition for observing the Opposition of Mars.

During the past year the Society has received from Mr. Gill the sum of £250, being the amount granted from the Government Fund of the Royal Society towards the expenses of his Expedition to Ascension.

Up to January 1, 1878, the Royal Astronomical Society had paid £400. 15*s.* 6*d.* towards the expenses of the Expedition; and during the past year a further sum of £99. 4*s.* 6*d.* has been paid to Mr. Gill, completing the sum guaranteed to him. Thus the Government Fund of the Royal Society and the Royal Astronomical Society have so far contributed equally to the expenses of the Expedition.

Mr. Gill, since his return from Ascension, has been busily engaged in reducing the observations made for the purpose of determining the solar parallax. A detailed report of the progress made in the reductions is given in the *Monthly*

Notices for December last (vol. xxxix., p. 51). Mr. Gill has received most important aid towards perfecting his work in the energetic co-operation of fourteen of the principal Observatories. From twelve of these he has received results of meridian observations of the *Mars* comparison stars, and in the *Monthly Notices* for January (vol. xxxix., p. 98) he has published a preliminary discussion of these results. Since that time he has also received a valuable series of results from Professor Lewis Boss, of the Dudley Observatory, Albany, U.S.

The discussion indicates the existence of considerable systematic discordances in the Right Ascensions obtained at the various Observatories, discordances three times greater than could be accounted for by systematic differences in the R.A. of the clock stars employed. These discordances have in part been traced to a personality or habit of observing, which is different for stars of different magnitude; but, besides this, there is a strong suspicion of systematic instrumental error at some of the Observatories. A circular has been issued with a request for further observations, and Mr. Gill is now engaged in discussing the heliometric triangulation of the stars. He hopes, as the result of these discussions, and by aid of the additional observations kindly promised, not only to obtain much information as to the cause of the discordances above referred to, but also to arrive at final places of the comparison stars of such high accuracy that they may be considered absolutely known in the final reduction of the *Mars* observations.

The greater part of the tabular distances of *Mars* from the comparison stars have been computed (employing approximate places of the comparison stars), so that, when the final star places have been arrived at, comparatively little time will be required for the formation of the final equations and their discussion.

The results of observations of α_1 and α_2 *Centauri* at Ascension have been published in the *Monthly Notices* (vol. xxxix., p. 126). Subsequent observations at Melbourne prove that these Ascension observations were made near the time of closest approach of the components of this interesting binary.

The observations in connection with the Expedition which have not yet been reduced are—

1. Moon culminations observed with the transit instrument.
2. Lunar distances measured with the heliometer from the Moon's limbs and from the lunar spot *Hypatia* B.
3. Measures of distance of the spot *Hypatia* B from the Moon's limb along known position-angles.
4. Measures of the diameters of *Mars* and *Saturn*.
5. Measures of the distance of *Mars* and *Saturn* near conjunction, Nov. 1, 2, 3, 4, and 5.
6. Measures of ϵ *Indi* from neighbouring stars.
7. Measures of *Melpomene* from comparison stars.

The discussions not yet begun are—

1. Deduction of longitude from (1), (2), and (3).
2. Discussion of the merits of the method of employing a lunar spot for longitude operations, and for determining the lunar parallax by the heliometer-diurnal method, with the data of (2) and (3).
3. Discussion of the employment of a similar method for future determination of the parallactic inequality.
4. Discussion of the tabular errors of *Melpomene*—the want of sufficient morning observations rendering a satisfactory discussion of the parallax impossible.

The completion of all the work still involves much labour, but no effort will be spared to lay the whole before the Society as soon as possible. Mr. Gill hopes to be able to present the determination of the solar parallax from *Mars* to the Fellows, in the shape of a volume of the *Memoirs*, before next winter session.

The Library.

The Council are glad to be able to report that the number of books taken out of the Library during the past year is more than 20 per cent. in excess of the number taken out during any former year, and the number of persons using the Library for purposes of reference has also considerably increased. The binding of the Society's books has been systematically proceeded with. 1,062 volumes have been bound in a substantial manner at a cost of £108. 15*s.* 10*d.*, and 343 volumes have been purchased from the Turnor Fund at a cost of £73.

The Library Committee also have pleasure in being able to report that during the past year they have completed the Society's series of the *Astronomische Nachrichten* at a comparatively trifling cost. It would be well if the Society possessed two copies of this valuable astronomical publication, one for reference in the library and the other for loan. The Society already (thanks to the gift of Miss Sheepshanks) possesses the first forty volumes in duplicate. These are the rarest part of the series, and there are also duplicate copies of several of the later volumes. During the past year the Library Committee have completed the Society's set of the *Sitzungberichte* of the Vienna Academy, and have also nearly made up their set of the *Berliner Jahrbuch*; the only missing volumes now being those for 1843 and 1861. The Committee are particularly anxious to complete the Society's set of the *Connaissance des Temps*, the first volume

of which was published in 1679. The Society's set commences in 1810; only a few odd volumes of the earlier part of the series are in the Library.

Amongst the presents to the Society's Library during the past year, a volume containing nearly a complete set of Mitchel's *Sidereal Messenger*, which was presented to the Society by Mr. Burnham—should especially be mentioned. As far as the Council are aware, this appears to be the only set of the *Sidereal Messenger* in England. The cataloguing of the Society's books has been commenced and is progressing. The Council hope that the work will be completed in the course of the present year.

Publications of the Society.

Vol. XLI. of the *Memoirs* has been somewhat delayed in consequence of Mr. Ranyard's visit to America. It was hoped that it would have been published during the past session; but the Council are glad to be able to report that the last chapter is now in the hands of the printers.

Vol. XLIV. of the *Memoirs* is also in the hands of the printers, and will shortly appear. It contains the following Papers:—

Mr. E. Neison. 'On a General Method of Treating the Lunar Theory.'

Mr. N. E. Green. 'Observations of *Mars* at Madeira, August and September 1877.'

Mr. Maxwell Hall. 'Opposition of *Mars* 1877.'

Mr. S. W. Burnham. 'Double Star Observations made in 1877–78 at Chicago with the 18½-inch Refractor of the Dearborn Observatory.'

The volume of the *Monthly Notices* which has appeared during the past year contains some valuable Papers by American and Continental Astronomers. The Council hope that the communication between English and Foreign Astronomers in the publications of the Society will continue to increase; but they take this opportunity of mentioning that some of the papers which have been received by the Society have not been printed, on account of their having been previously published abroad.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associate during the past year :—

Fellows :—Captain L. C. Bailey.
E. B. Beaumont.
Joseph Bonomi.
Rev. J. Booth.
John Carter.
W. R. Cooper.
S. M. Drach.*
H. S. Ellis.
Rev. C. Gribble.
Rev. P. Holmes.
Henry Johnson.
Rev. R. Main.
John Matheson.
Henry Mugridge.
J. W. Nichol.
G. G. G. F. Pigott.
G. V. Vernon.
Sir A. S. Waugh.

Associate :—Padre A. Secchi.

Joseph Bonomi was born on October 9, 1796, at 76 Great Titchfield Street, in the parish of Marylebone. His father was by birth an Italian, and an architect by profession. He had been for some time the architect of St. Peter's at Rome, but had been induced by James and Robert Adams, the well-known architects of the period, to leave Rome and come to London, where he remained for a considerable time in their employment. He married Rosa Florini, a cousin of Angelica Kauffman, and after his marriage returned to Rome, seemingly with the intention of carrying on his profession there; but the death of her child so distressed the mother that they again returned to England, where Bonomi commenced work and was very successful in its practice. The Sardinian chapel and Montagu House, in London, are from his designs; also Eastwell House, in Kent, now the property of the Duke of Edinburgh; Roseneath, on the Clyde, a mansion belonging to the Duke of Argyle; and many well-known country seats. The elder Bonomi died in the house in Great Titchfield Street, on March 9, 1808. His wife survived him until June 1812. He left four sons. James was killed at the battle of Assaye, 1803. Charles, also in the army,

* An obituary notice of Mr. Drach will appear in the next Annual Report.

died in 1843. The eldest, Ignatius, followed his father's profession, and died in 1870. The subject of this notice, Joseph, had a twin sister and two other sisters; and these complete the family circle. His parents were Roman Catholics and foreigners, yet Mr. Bonomi's education and ideas were thoroughly English. Art influences began very early to associate themselves with him; we have an illustration of this at the baptism of the twins, which took place in the Venetian Chapel when they were only four days old. The sponsors were Dom. John Charles Bonomi and Angelica Kauffman: they were not present, but were represented by Dom. Bartholomeo Ruspoli, military knight, and Maria Cosway. The celebrated patriot, General Paoli, was his sponsor at his first communion.

Joseph Bonomi was chiefly educated at a school in Carshalton, Surrey; after which he became a student of the Royal Academy, and gained the silver medal for the best drawing from the antique, and also for the best model from the antique in sculpture. Sculpture was the branch of art which he took to, and to carry it out he was placed with Nollekens, the sculptor.

In 1823 he went to Rome to continue his studies, and there made the acquaintance of Gibson, a friendship which only ceased with life.

In 1824 he left Rome, and went with Robert Hay, a naval officer, to Egypt, where he remained a number of years, working with Mr Arundale and others for Mr. Hay.

While at Medinet Habou in October 1825, he mentions in his journal the arrival of his friend Burton.

At the end of 1826 he left Mr. Hay and returned to Cairo, where Burton was making plans of the Pyramids and tombs.

In 1828 he accepted an engagement to assist Burton with drawings on the stone for his "Excerpta Hieroglyphica." This work they continued together for some time.

In 1829 he made another journey up the Nile on his own account, and revised his copies of the inscriptions &c.

In October 1829 he commenced a journey to Dongola, which he reached in November and left in December.

In 1831 he again went up the Nile and accompanied Linant in his expedition to the gold mines in the Desert between the Nile and the Red Sea. They returned to Cairo at the end of the year. Next year Bonomi paid his long desired visit to Bishereen Desert, where he remained about two months.

In 1832–3 he was again working for Hay, and returned to Cairo. At the end of August he, with Catherwood and Arundale, took leave of their friends and started for Sinai and the Holy Land. Bonomi visited the ancient temple and remains at Sarabat el Khadem. He copied many of the inscriptions on the Gebel, crossed the Wady Mokatteb and the Wady Fairan, and reached Sarabat on September 9. Of the Egyptian temple he made a plan, with measurements. In the same month he rejoined his companions at the Convent on Mount Sinai; and on

the 22nd the whole party started for Gaza. They entered Jerusalem on October 9. Bonomi, having adopted the Mahometan dress, and completely identified himself with the manners and habits of the people, managed to enter the Haram es-Sherif; he was followed by Arundale and Catherwood, and they managed to take plans of the buildings as well as sketches (*see* "Quarterly Statement of Palestine Exploration Fund," January 1879).

In 1834 he was still travelling in Syria, and remained some time at Damascus and Baalbeck. At the end of 1834 he returned to England.

A considerable portion of 1835–6 was passed in the north of England and Scotland. While in Yorkshire, Bonomi executed several works in sculpture. Much of the next two years appears to have been occupied with work connected with his Egyptian travels.

In 1838 he was in Rome, measuring and copying the hieroglyphs on the obelisks, and was in England again during the same year. In 1839 he was working for the British Museum. In 1840 and 1841 he was still in London, engaged on the illustrations of Wilkinson's "Manners and Customs of the Ancient Egyptians." In 1841 he was also engaged, with Birch and Arundale, in bringing out a book called the "Gallery of Antiquities."

In 1842 he went again to Egypt, at two days' notice, with the Prussian Expedition. Having accidentally met the members of the party—the Crown Prince of Prussia, now Emperor of Germany, Humboldt, Bunsen, and Lepsius—at the British Museum, at that time on their way to Southampton to take steamer for Egypt, the idea that his former experience would be useful led to the suggestion that he should go with the party. They left Southampton on the 1st of September. Bonomi did not return to England until September 1844.

In September 1845 he married Jessie, daughter of John Martin, the celebrated painter, by whom he left issue.

In 1849 or 1850 he furnished the drawings and, in conjunction with Warren and Fahey, he painted a panorama of the Nile, which was exhibited with considerable success in London and the provinces. It afterwards went to America.

In 1853 he assisted Owen Jones in the works of the Crystal Palace Egyptian Gallery.

In 1860 he left England with the "Himalaya" Expedition to Spain to observe the total solar eclipse of July 18 from Miranda de Ebro. (See *Monthly Notices*, vol. xxi., p. 1.)

In 1861 he was appointed, by the Royal Academy, Curator of Sir John Soane's Museum, in Lincoln's Inn Fields, a position which he occupied till his death, on March 3, 1878, at "The Camels," his own residence at Wimbledon Park.

During the year 1867 the Hieroglyphic Dictionary of Dr. Birch was published by Longmans, in the 5th volume of Bunsen's

"Egypt's Place in Universal History." The hieroglyphic type for this work was cast by Mr. Branston, from designs drawn by Bonomi, and was at that time the only fount of the kind in England.

As an artist of hieroglyphics and Egyptian sculptures &c., Mr. Bonomi has never been equalled.

His principal works are:—Nineveh and its Palaces; Papers to the Society of Biblical Archæology, Royal Society of Literature, Syro-Egyptian Society, &c. &c.; numerous works in conjunction with Mr. Samuel Sharpe; Catalogues of Egyptian Collections—for example, Dr. Abbott's, The Hay Collection, Sir Charles Nicholson's, Hartwell Museum, &c. &c.

The work of which he himself thought most was a complete transcript of the Vignettes and Hieroglyphics upon the Sarcophagus of Seti I., called Belzoni's Sarcophagus, and preserved in the Soane Museum. It was published in nineteen lithographic plates, with an introduction by Samuel Sharpe, London, Longmans, 4to., 1864, under the title of "The Alabaster Sarcophagus of Ormenepthah I., King of Egypt." The above facts are derived from a memoir of Mr. Bonomi prepared by Mr. W. Simpson for the Society of Biblical Archæology, and we are indebted for them to the kindness of Mr. W. Harry Rylands.

Mr. Bonomi was elected a Fellow of the Royal Astronomical Society on February 8, 1861.

James Booth, LL.D., F.R.S., was born at Lava, county Leitrim, on August 25, 1806. He entered Trinity College, Dublin, in 1825, and was elected scholar in 1829. He graduated B.A. in 1832, M.A. in 1840, and LL.D. in 1842. In 1834 he received Bishop Berkeley's gold medal for Greek. He was a candidate for a fellowship, and in 1835 was placed second among the unsuccessful candidates, in 1837 first, in 1838 fourth, in 1839 first, and in 1840 second, receiving a premium on each occasion, and the Madden premium in 1837 and 1839, when he was first.

In 1840 the four candidates who received premiums were George Salmon, James Booth, William Roberts, and Michael Roberts, all well-known mathematicians. Dr. Salmon and Mr. William Roberts were elected Fellows in 1841, and Mr. Michael Roberts was elected in 1843, but Dr. Booth does not appear to have become a candidate again. Having thus so narrowly failed to obtain a Fellowship, Dr. Booth left Ireland in 1840, and in the same year was appointed Principal of Bristol College, an office which he held till 1843. Among his colleagues at Bristol were Mr. F. W. Newman, who was professor of classics, and Dr. W. B. Carpenter, who was professor of natural philosophy and natural history. Dr. Booth was ordained deacon by the Bishop of Exeter in 1842, and priest in the same year, by the Archbishop of Canterbury. In 1843 he was appointed Vice-principal of the Collegiate Institution, Liverpool. He

held this position till 1848, when he came to London, and was engaged in writing educational works and lecturing for the Society of Arts. In 1854 he was appointed to the sole charge of St. Anne's, Wandsworth, and in 1859 was presented to the vicarage of Stone, Buckinghamshire, by the Royal Astronomical Society. This living he held till his death, which took place on April 15, 1878. He was also chaplain to the Marquis of Lansdowne for twenty years. In 1864 he was appointed a Justice of the Peace for Buckinghamshire. He married Mary, daughter of Daniel Watney, Esq., of Wandsworth, who died in 1874. Dr. Booth leaves two sons and one daughter; and his sister Maria, who always lived with him, survives him.

Dr. Booth's writings were chiefly mathematical and educational. The former show him to have been an able and original mathematician, and the latter exercised considerable influence on the promotion of education among the middle and industrial classes.

His earliest printed paper appeared in the *Philosophical Magasine* for 1840, under the title "On the Focal Properties of Surfaces of the Second Order"; but before this he must have devoted considerable time to his method of tangential coordinates by which his name is best known to mathematicians. This method was published in 1843, in an octavo tract of 32 pages, entitled "On the Application of a New Analytic Method to the Theory of Curves and Curved Surfaces," the pages being headed "On Tangential Coordinates." The preface is dated March 25, 1840,* but the date on the title-page is 1843 and the author is described as "Professor of Mathematics in the Collegiate Institution, Liverpool." The method is not the same as that generally known by the name of tangential coordinates, viz. in which the position of a line is fixed by the perpendiculars let fall upon it from three fixed points, or, more conveniently, by the ratios of these perpendiculars, for in Dr. Booth's system the coordinates of a line are the reciprocals of the intercepts on two fixed axes. Thus, the ordinary equation of a straight line in Cartesian coordinates is $\frac{x}{a}+\frac{y}{b}=1$: if now we fix the point (x, y) and let a, b vary, this point may be regarded as determined by the same equation. Putting $\xi=\frac{1}{a}$, $\nu=\frac{1}{b}$, the equation becomes $x\xi+y\nu=1$; and, ξ, ν being the variables, this is the tangential equation of the point (x, y) in Dr. Booth's form; while, if x, y be variables, the equation denotes the straight line whose intercepts on the axes are $\frac{1}{\xi}$ and $\frac{1}{\nu}$. It is this duality of interpretation which is of capital importance; of more importance, indeed, than the invention of the new system of coordinates.

* This date would seem to imply that the tract was originally printed in 1840; but there is nothing else in the 1843 copies to indicate a previous edition, and we have seen no copy of earlier date.

Professor Cayley, in the first chapter of the second edition (1873) of Salmon's *Higher Plane Curves*, writes in reference to line coordinates in general: "There is little occasion for any explicit use of line coordinates: but the theory is very important; it serves in fact to show that in demonstrating by point coordinates any descriptive theorem whatever, we demonstrate the correlative theorem deducible from it by the theory of reciprocal polars (or that of geometrical duality): viz., we do not demonstrate the first theorem and deduce from it the other, but we do at one and the same time demonstrate the two theorems: our (x, y, z) instead of meaning point coordinates may mean line coordinates, and the demonstration is in every step thereof a demonstration of the correlative theorem."

The ξ and ν tangential coordinates invented by Dr. Booth have been sometimes referred to in England as Boothian coordinates; but in point of fact they had been introduced by Plücker as early as 1830, in a paper, "Ueber eine neue Art, in der analytischen Geometrie Puncte und Curven durch Gleichungen darzustellen" (*Crelle's Journal*, t. vi., pp. 107–146). Plücker considers a straight line $Ay+Bx+C=0$, where A, B, C are connected by an equation $aA+bB+cC=0$, a, b, c being constants. The straight line then always passes through the point given by $cy-a=0$, $cx-b=0$. Treating A, B, C as variables, and denoting them by u, v, w, he regards the equation $au+bv+cw=0$ as representing the point $\left(\frac{b}{c}, \frac{a}{c}\right)$.

If the equation be written in the form $\frac{a}{c}\cdot\frac{u}{w}+\frac{b}{c}\cdot\frac{v}{w}+1=0$, this becomes identical with Dr. Booth's system on taking $w=-1$. There is no question therefore that the Boothian tangential coordinates are really due to Plücker. Dr. Booth's discovery was a perfectly independent one; and his system differs from Plücker's in one detail, viz. the equations are not homogeneous. Dr. Booth seems to have been led to his system of coordinates by the "anomalous fact in the application of algebraic analysis to geometrical investigations, that while the locus of a point could be found from the simplest and most elementary considerations, the envelope of a right line or plane could be determined only by the aid of principles, artificial and obscure, derived from a higher department of analysis" (*Tangential Coordinates*, 1843, p. 1).

The Plückerian or Boothian coordinates may be said to stand in the same relation to three-point tangential coordinates (in which perpendiculars are let fall from three fixed points) as Cartesian coordinates stand to trilinear; for in the latter case one side of the triangle of reference and in the former case two of the points of reference move off to infinity. The connexion is exhibited in the first chapter of Salmon's *Higher Plane Curves* (first edition, pp. 13, 14, and second edition, p. 9). Dr. Booth's original tract contained only 32 pages, but he continued to develope the subject

and in his *Treatise on some New Geometrical Methods* (1873) more than 200 pages are devoted to this method of tangential coordinates, a good many examples being included. A number of questions have in recent years appeared in the *Educational Times*, which have been worked out by this system of coordinates, and some of these are reprinted at the end of the second volume of *New Geometrical Methods* (1877), pp. 424–440. It has been thought desirable to enter thus fully into the subject of tangential coordinates because it is in connexion with this field of research that Dr. Booth's name is most familiar to mathematicians, and also because, although he was anticipated by Plücker,* the independent discovery by Dr. Booth of the analytical equivalent to the geometrical theory of reciprocal polars is not without historical interest.

Next to tangential coordinates and reciprocal polars, the subject on which Dr. Booth's writings are most considerable and important is that of elliptic integrals, especially in connexion with the motion of a rigid body round a fixed point. His memoirs "On the Geometrical Properties of Elliptic Integrals" were published in the *Philosophical Transactions* for 1852 and 1854, and his papers on the motion of a rigid body round a fixed point appeared in the *Philosophical Magazine* and other journals. In these researches the author confines himself to the elliptic *integrals* of Legendre, and does not employ the elliptic *functions*—inverse to the integrals—introduced by Abel and Jacobi; and while he was thus perhaps hindered from carrying his investigations as far as he might otherwise have done, the same reason has probably prevented his writings from being much studied. But however this may be, Dr. Booth's papers certainly represent a great amount of very valuable and original research.

In relation to this subject should also be mentioned his memoir "On the Trigonometry of the Parabola, and the Geometrical Origin of Logarithms," which was printed *in extenso* in the *British Association Report* for 1856. The memoir relates to elliptic integrals in the case in which the modulus is unity. In elliptic functions if the modulus k be put equal to zero, the theory becomes identical with circular trigonometry, and if k be put equal to unity, the theory becomes that of parabolic trigonometry. The length of an arc of a parabola, of latus rectum $4m$, measured from the vertex, $= m \sec\theta \tan\theta + m\int \sec\theta\, d\theta$; and, in the case of $k = 1$, the first elliptic integral

* Dr. Klein states (*Fortschritte der Mathematik*, t. ii., 1870, p. 453) that in the second volume of his *Analytisch-geometrischen Entwickelungen* (1831) Plücker has also employed tangential coordinates, and he adds that, although tangential coordinates were first introduced by Plücker in the paper in the sixth volume of *Crelle* cited above, the idea of representing a straight line by coordinates was made use of by Möbius in his *Barycentrischer Calcul* of 1827. See also Salmon's *Conics* (5th Edit., 1869), p. 266.

$$= \mathrm{F}(\phi) = \int \frac{d\phi}{\cos\phi} = \log\tan\left(\tfrac{1}{4}\pi + \tfrac{1}{2}\phi\right).$$

Dr. Booth's notation is peculiar: he introduces the symbols $\perp$ and $\top$ (which have some resemblance in their mode of application to $+$ and $-$), defined by the equations

$$\tan(\phi \perp \chi) = \tan\phi\sec\chi + \tan\chi\sec\phi,$$
$$\tan(\phi \top \chi) = \tan\phi\sec\chi - \tan\chi\sec\phi.$$

In the case of $k = 1$ we have in Elliptic Functions

$$\tan\mathrm{am}(u+v) = \tan\mathrm{am}\,u\sec\mathrm{am}\,v + \tan\mathrm{am}\,v\sec\mathrm{am}\,u;$$

so that if $\phi = \mathrm{am}\,u$, $\chi = \mathrm{am}\,v$, then $\phi \perp \chi = \mathrm{am}(u+v)$ viz.

$$\left.\begin{aligned}\phi \perp \chi &= \mathrm{am}(\mathrm{am}^{-1}\phi + \mathrm{am}^{-1}\chi)\\ \phi \top \chi &= \mathrm{am}(\mathrm{am}^{-1}\phi - \mathrm{am}^{-1}\chi)\end{aligned}\right\}(\mathrm{mod}\ \ .$$

The theory thus belongs to the particular case $k = 1$ of Elliptic Functions, studied by Gudermann, and for which the amplitude becomes the function termed by Professor Cayley the gudermannian, and written by him gd u (Cayley's *Elliptic Functions*, p.56). Dr. Booth's trigonometry of the parabola is thus a geometrical illustration of the theory of the gudermannian.

Dr. Booth republished the whole of his mathematical writings, with considerable additions, in two volumes, entitled *A Treatise on some New Geometrical Methods*. This work is dedicated to the President and Council of the Royal Astronomical Society. The first volume, which relates chiefly to tangential coordinates and reciprocal polars, was published in 1873; the second, which appeared in 1877, contains the papers on elliptic integrals, and there is also a treatise on the conic sections, each property being obtained directly from the cone, which is here printed for the first time, although the substance of it was communicated to the Royal Irish Academy as long ago as 1837. In the introduction to this work the author writes, "It has been to me a heavy drawback and deep discouragement that I have had no fellow workers to share in these researches. Neither have I entered into the labours of any. Without sympathy and without help I have worked upon those monographs presented to the public." The English mathematician who devotes himself to one or two special subjects can scarcely expect to have many fellow workers among his countrymen, but the theories to which Dr. Booth's writings relate have been enormously developed on the Continent in the last fifty years, and the comparative neglect to which he alludes may be traced to the fact that it is these foreign researches which, being expressed in more modern forms, have been generally referred to. For example, the investigations of Jacobi and those who have fol-

lowed him on the motion of a rigid body round a fixed point, in which the theta functions are employed, are naturally better known than that of Dr. Booth, in which only the integrals appear.

In 1846, when at Liverpool, Dr. Booth published a tract of 108 pages on *Education and Educational Institutions considered with reference to the Industrial Professions and the Present Aspect of Society*, and also, in the same year, an Address to the Literary and Philosophical Society of Liverpool, of which he was President. He also published in 1847 *Examination the Province of the State; or, the Outlines of a Practical System for the Extension of National Education* (pp. 73), which attracted a good deal of attention. Dr. Booth was treasurer and chairman of the Council of the Society of Arts from 1855 to 1857, and during this period he delivered many lectures relating to education, some of which were printed as pamphlets. Several of his addresses were published by the Society of Arts under the titles *Systematic Instruction and Periodical Examination* (1857) and *How to Learn and What to Learn* (1857), and the latter went through several editions very rapidly. Dr. Booth also edited, and wrote the introduction to, the volume of the *Speeches and Addresses of His Royal Highness The Prince Albert* which was published by the Society of Arts in 1857. By his lectures and writings, as well as by his influence as Chairman of the Council, Dr. Booth may almost be said to have founded the Society of Arts' system of examinations. It is true that examinations had been held in 1854 and 1855, but very few candidates had presented themselves. In 1856, the first year in which Dr. Booth's plan was adopted, there were 52 candidates, the examination being held only in London, and in 1857, when the examinations were held at London and Huddersfield, there were above 200 candidates. Dr. Booth retired from the Council of the Society in 1857 in consequence of a difference of opinion between himself and the Council, the main point in dispute being as to whether the examinations should be partly oral, as Dr. Booth desired, or should be conducted wholly by printed papers, as proposed by Mr. Harry Chester, of the Privy Council Office, and adopted by the Council. It should be remembered that at this time the Oxford and Cambridge local examinations had not been founded, and the only public examination open to the middle and industrial classes was that of the College of Preceptors.

As a preacher Dr. Booth was eloquent, and when minister of St. Anne's, Wandsworth, attracted large congregations. When in 1859 the vicarage of Stone, the advowson of which had been given to the Royal Astronomical Society by Dr. Lee in 1844, became vacant, it was felt that Dr. Booth's services to science and to education gave him a strong claim to the appointment, and although not then a Fellow of the Society, he was (with the full approbation of Dr. Lee, who was a member of Council at the time) presented to the living, in which he succeeded the late Rev. Joseph Bancroft Reade, F.R.S., well known in connexion

with the early history of photography, microscopy, &c. Among Dr. Booth's theological writings may be mentioned *The Bible and its Interpreters* (1861), *A Sermon on the Death of Admiral W. H. Smyth, D.C.L., F.R.S.* (1865), and *The Lord's Supper, a Feast after Sacrifice* (1870). Dr. Booth was elected a Fellow of the Royal Society on January 22, 1846, and of the Royal Astronomical Society on June 10, 1859.

J. W. L. G.

Mr. W. R. Cooper was born in 1843. He was for many years assistant curator, under the late Mr. Joseph Bonomi, of Sir John Soane's Museum in Lincoln's Inn Fields. Here he imbibed an enthusiastic love of archæological studies, and became acquainted with others interested in similar subjects. On the formation of the Society of Biblical Archæology he was chosen as secretary, an office which he retained till his death. In this capacity he greatly assisted the late Mr. George Smith in bringing his discoveries before the public. He also had a large share in editing the valuable series of volumes entitled *Records of the Past.* Besides these semiofficial duties he published several works of his own, amongst which should be mentioned *The Serpent Myth, The Myths of the Horus and Osiris, Egypt and the Pentateuch, Egyptian Obelisks, Heroines of the Past,* and particularly his large and important *Archaic Dictionary.* Mr. Cooper was elected a Fellow of the Royal Astronomical Society in January, 1875. During the last two years his health rapidly failed, and he was obliged to remove permanently to Ventnor, where he died on November 15, 1878.

Henry Samuel Ellis, of Exeter, died on May 13, 1878, in the fifty-third year of his age, at Holmwood, the seat of J. J. Barrow, Esq., Tunbridge Wells, where he was on a visit for a few days; the cause of his death being disease of the heart. In early life he had a taste for scientific pursuits, and took some interest in botany. In a quiet and unassuming manner he made his influence felt in any undertaking in which he was engaged; and he was mainly instrumental in altering the time in Exeter and throughout the West of England, from Bath westward, from local to Greenwich time. In support of all scientific movements in Exeter, Mr. Ellis was most earnest. It was chiefly through his exertions that the British Archæological Association was brought to Exeter; he actively assisted in establishing the free library and museum in that city, and was one of the first to support the local School of Science. Mr. Ellis was mayor of Exeter in 1869, when the meeting of the British Association was held there, and many will remember how admirably he carried out the duties of his office. For many years he regularly attended the meetings of the British Association, and it was this fact, in connexion with the interest

he manifested in aiding to bring the Association to Exeter, that induced the Town Council to elect him an alderman, in order that he might be mayor when the Association visited the city.

Mr. Ellis gave much time and attention to railway business. He was the prime mover, if not the originator, of the Railway Shareholders' Association, and at the time of his death he was chairman of two railway companies, the Culm Valley and the Brixham, and director of many others. He was a director of the Bristol and Exeter Railway until its purchase by the Great Western Railway Company.

Mr. Ellis was elected a Fellow of the Royal Astronomical Society on February 9, 1855, and was one of the party who went to Spain in the 'Himalaya' to observe the total solar eclipse of 1860, July 18, and landed at Santander (*Monthly Notices*, xxi., p. 1). He leaves a widow, six sons and one daughter.

Dr. Peter Holmes, D.D., was born in the town of Plymouth. In 1837 his father sent him to Oxford, where he obtained his B.A. degree in 1840, his M.A. in 1844, and his D.D. in 1859. He was ordained deacon by the Bishop of Exeter in 1840, and priest in the following year. In December 1841 he was elected a Fellow of the Royal Astronomical Society. He was given the curacy of Sheepstor in 1840, of Bickleigh in 1843, and of Egg Buckland from 1847 to 1861. For seven years he was Diocesan Inspector of Schools in the Deanery of Plymouth, and from 1868 acted as curate at Pennycross. For many years he was the Head Master of the Plymouth Grammar School; and he afterwards carried on a private school at Mannamead. The greater part of his life may be said to have been devoted to education, for which he was eminently qualified. He was a man of high attainments, most genial and warmhearted in manner, and had the merit of winning the love of his pupils, and creating in them a lasting interest in him during their future lives. Dr. Holmes led an active and useful life. His sonorous tones were frequently heard at the Plymouth Institution, over which he had presided as its President, and his portly frame and ready utterances will be sadly missed there. Of late years he generally officiated on Sundays in the services at Pennycross Chapel, and was ready at all times to give cordial assistance to those who sought his aid.

His literary attainments were of the highest order, and the profound and scholarly character of his mind may be judged from a list of his works taken from the *Clerical Directory*: "Observations on the Standard of Doctrine in the Church of England," 1848; "Translation of Bishop Bull's *Defensio Fidei Nicænæ*," 2 vols. for the Anglo-Catholic Library, Oxford, 1851–52; "Translation of Bishop Bull's *Judicium Ecclesiæ Cathol.*," ibid., 1855; "Treatise on Diocesan Synods," 1852; Articles on "Greek Testament Criticism" in the *Christian*

Remembrancer, and also in the third edition of Kitto's *Biblical Cyclopædia*, viz. "Divination," "Ham," "Jesus Christ," "Laws of Moses," and about fifty others, 1860–66; "On the Irish Church Question," 1868; "On the Connection between Church and State," a paper read at a Synod of the Plymouth Deanery; also Tertullian's "Five Books against Marcion," translated for Clark's *Ante-Nicene Christian Library*, Edinburgh, 1866; also Tertullian's "Ad Nationes," in the same series, 1869; Tertullian's "De Præscriptione Hæreticorum," "Adversus Hermogenem," "Adversus Valentinianos," "De Carne Christi," "Adversus Praxean," and other tracts by the same Father, translated for the same series, 1870; "The Anti-Pelagian Works of St. Augustine"; "De Peccatorum Meritis et Remissione"; for Clark's English Edition of St. Augustine's Works, 1871; and fourteen other treatises in 8vo. volumes.

Dr. Holmes was domestic chaplain to the Countess of Rothes. He leaves a widow, but no children.

Henry Johnson resided at 39 Crutched Friars, London, E.C., where he carried on the business of a wine merchant. He was much attached to mechanical pursuits, and erected a workshop at the top of his house, where he constantly employed one or two skilled workmen. He was the inventor of the *Volutor*, an apparatus for describing spirals, which is described in the *British Association Report* for 1869 (Transactions of the Sections, p. 60), and of a deep sea pressure gauge (see *British Association Reports*, Transactions of the Sections, 1859, p. 236, and 1860, p. 202). The object of the latter was to determine the pressure of the water at great depths in the sea by means of the compression of the water contained in the instrument, which may be regarded as a small hydraulic press, of which the ram is forced into the cylinder by the increasing pressure of the sea when sinking, and expelled by the expansion of the water in the cylinder when rising. Both instruments were exhibited in the Exhibition of 1862, and are described in the official report of the Jurors, Class XIII., pp. 16 and 41. Mr. Johnson also exhibited a metallic deep sea thermometer, to be used in experiments with his deep sea pressure gauge, so contrived that the indications of the instrument were not at all liable to be disturbed by the great pressure of the water upon it (*Ibid.* p. 38). He made numerous experiments with the deep sea pressure gauge in comparatively deep water off the Isle of Wight. For six or seven years before his death he had become completely broken down in health, and had resided chiefly at Worthing. Mr. Johnson never married.

The Rev. Robert Main, M.A., F.R.S., was born at Upnor, in Kent, on the 12th of July 1808, and was educated at a

private school of deservedly good repute at that time, which was conducted by a sound mathematician (the Rev. J. Neave), whose memory he always held in great esteem, and to whom he considered himself indebted throughout his after career for the good education he received from him, more especially for the knowledge of Euclid and Algebra beyond what was usually taught in those days. After leaving school he became engaged in tuition as a master in the Grammar School at Bishop's Waltham, Hants (of which the Rev. T. Scard was the head master), where he remained until he left it for Cambridge. In 1831 he entered Queens' College in that University, and after a successful course of study graduated as Sixth Wrangler in 1834. He was shortly afterwards elected to a Fellowship, but did not reside at Cambridge very long, for, on the appointment of Professor (now Sir George) Airy in the year 1835 to succeed Mr. Pond as Astronomer Royal, he was offered and accepted the office of First (or, as it is now called, Chief) Assistant at the Royal Observatory, which necessitated his removal to Greenwich. The published volumes of the Royal Observatory from 1836 to 1860 supply sufficient evidence of the energetic way in which Mr. Main supported the Astronomer Royal in the measures he took to carry on the scientific operations of that establishment. Everyone who has had much to do with large observatories well knows the great value of such support, and it is to Mr. Main's careful superintendence of the observations and subsequent calculations for very nearly a quarter of a century that a considerable part of their accuracy and completeness is due.

But although his application to these duties occupied for so long an interval the principal part of Mr. Main's time, the publications of the Royal Astronomical Society witness that his scientific energy was by no means thus exhausted. He availed himself of every opportunity of utilising the results obtained at Greenwich for the benefit of practical and theoretical astronomy, and we shall notice briefly a few of the applications to which they were, in his hands, thus applied. The first of these, we believe, consists of a series of papers on the correction of the Elements of the Orbit of *Venus*, published in 1837 and 1838, and in which the observations of that planet by Professor Airy, at Cambridge, during the years 1833–35 are made use of for comparison with the *Nautical Almanac* places then derived from Lindenau's Tables, as well as later observations obtained at the Royal Observatory. In 1840 Mr. Main contributed a paper to the Society, "On the present state of our knowledge of the Parallax of the Fixed Stars." Such knowledge was then but small, and till recently much more of a negative than a positive kind; but it is always of great importance that attention should be called to the existing state of a subject in which there is reason to suppose that considerable advances are shortly to be expected, and we need hardly remark that this was then

the case with the problem, so long supposed to be insoluble, of the parallax and distance of the fixed stars. In February 1841 Mr. Main was elected one of the Honorary Secretaries of the Society, and for some years the duties of that office were ably discharged by him, in conjunction, first with Mr. Rothman, and afterwards with Mr. Galloway. On his retirement therefrom in 1846, the Council acknowledged his services in the following words:—"In addition to the zeal in behalf of the Society which has actuated him, in common with others, Mr. Main has brought to the duties of his office a close acquaintance with practical astronomy as well as theoretical, and the habits of order demanded by a daily attention to astronomical duties more onerous than those of our Secretaryship. So heavy, indeed, are these last that the Council acknowledge peculiar obligations to the gentleman who, residing at so great a distance, and pressed by public calls of such magnitude, has for years found time to be the constant superintendent of the routine of our business and a regular attendant at our meetings." In reference to the paper before mentioned on the parallax of the fixed stars, we may quote the words of Sir John Herschel in his speech on giving the Gold Medal of the Society to Professor Bessel in 1841, for his noteworthy success in first obtaining, in the case of 61 *Cygni*, a parallax generally acknowledged to be trustworthy and claiming the acceptance of astronomers. "In whatever reference," he says, "I may have to make to the history of the subject, I must take this opportunity to acknowledge my obligations to the author of this paper, as well as for his exceedingly luminous exposition of the results of those more successful attempts on the problem by Henderson, Struve, and Bessel, which I shall now proceed more especially to consider." And further on—"This is the final and severe test: Mr. Main has applied it, and the results have been placed before you—*oculis subjecta fidelibus*. If all this does not carry conviction along with it, it seems difficult to say what ought to do so."

On resigning the secretaryship, Mr. Main was elected one of the Vice-Presidents of the Society. In 1849 he contributed to the Society a paper on the form of the planet *Saturn*, suggested by Sir William Herschel's conjecture, from repeated estimations, that its figure was not elliptical but "like a parallelogram with the corners rounded off." Mr. Main gives a series of careful measurements with a micrometer in 1848 and 1849, the result, which was confirmed in subsequent papers, appearing to establish the perfect ellipticity of the planet's shape. In 1850 appeared his first paper on the important subject of the proper motion of the fixed stars. The final result of the discussion and determination of the proper motion of all stars contained both in Bessel's *Fundamenta* (formed from Bradley's Greenwich observations) and in Airy's Twelve-Year and Six-Year Star Catalogues are too well known to astronomers to need any detailed description here. The next paper of importance communicated by Mr. Main was published in 1855, and contains an investigation of the

of aberration thus found was 20″·34, which is entitled to considerable confidence. Mr. Main also made a fresh determination from these observations of the annual parallax of γ *Draconis*. As before, the result was a small negative quantity, proving only that the true value was exceedingly small.

Mr. Main retired from the chair of the Society in February 1861. But before that occurred, an important event in his life had taken place to which reference has already been made. On the 1st of March 1860, Mr. Manuel J. Johnson died, after having devoted nearly twenty years to directing the work of the Radcliffe Observatory. The trustees, in the month of June 1860, nominated Mr. Main to succeed him, and thus terminated his long connection with the Royal Observatory. The Astronomer Royal, in his Report to the Board of Visitors on the 1st of June 1861, expresses himself thus:—"Mr. Main, who had for twenty-five years held the office of First Assistant, and to whose zeal and orderly assiduity and honourable conduct on every occasion the position of the Observatory is in no small degree due, accepted in the last summer the office of Radcliffe Observer at Oxford, and on September 30 resigned his occupation at the Royal Observatory."

The last paper Mr. Main contributed to the Society before his removal to Oxford was one read at the meeting on April 13, 1860, entitled "Remarks on the Controversy respecting the Secular Acceleration of the Moon's Mean Motion." This paper is supplementary to the one on the same subject we have already referred to; deprecating any definite general conclusion on the whole matter before the publication of the theories of Hansen and Delaunay, but contending that there was very great reason to accept the conclusion of Adams and Delaunay, and to believe that "they have given the correct value of the acceleration depending on the diminution of the eccentricity of the Earth's orbit." It was called forth by a paper of Dr. Hartwig, of Schwerin, who had misunderstood Mr. Main's views on the point in consequence of his non-reference to it in the speech on the presentation of the medal to Professor Hansen.

At the meeting on January 11, 1861, he gave from the chair a short account of the proceedings at the Radcliffe Observatory since the decease of Mr. Johnson and his own appointment as Radcliffe Observer, and in the following May he communicated some observations of his own of phenomena of *Jupiter's* satellites made with the telescope of the heliometer at that Observatory. This instrument was constructed by Messrs. Repsold, of Hamburg, and formed a valuable addition to the instrumental equipment of the Radcliffe Observatory. From unavoidable delay in its completion, it was not received at the Observatory until the winter of 1848; a detached building was erected for it the following summer, and in October the instrument was set up under the personal superintendence of Adolph Repsold. The object-glass (made by Merz, of Munich)

has an aperture of 7½ inches and a focal length of 10 feet 6 inches. A great improvement in the meridional observing took place under Mr. Main's directorship through the purchase of the Transit Circle which had been used by Mr. Carrington at Redhill. The diameter of the object-glass of this instrument is 5 inches and its focal length 66 inches. It was removed to Oxford in the summer of 1861, and observations with it commenced in 1862. Mr. Main was soon able to endorse Mr. Carrington's statement as to its excellence; and the meridional instruments previously in use were now superseded for Observatory purposes, being retained, however, in the building for practice, if required, by students of the University.

From the time we have mentioned, almost to that of his decease, Mr. Main continued most assiduously to apply himself to keeping up and extending the reputation of the Radcliffe Observatory; the zeal and diligence with which he did so being sufficiently evidenced in the successive volumes of observations which have punctually and regularly made their appearance year by year.

Not long before Mr. Main's appointment, Mr. Johnson had completed the scheme of star-observation on which he had for some years so usefully employed that part of the resources of the Observatory—the reobservation of the stars of Groombridge's Catalogue, from which much valuable information respecting stellar proper motion &c. has been derived. On its completion he had prepared a list of remarkable stars which he thought it desirable to have carefully reobserved, consisting chiefly of stars of greater magnitude than the third, stars within 6° of the North Pole, and stars possessing physical peculiarities, or having orbital proper motion. This list Mr. Main made it his first care to complete, and he accomplished it by the end of 1861, although the Catalogue containing the observations (reduced to the epoch 1860) could not, owing to the pressure of other work, be published till 1870. The Catalogue in question contains no less than 2,386 stars, and forms the "Second Radcliffe Catalogue," the observations on which it is founded being made from the years 1854 to 1861 inclusive. With 1862, as we have mentioned, commenced the observations with the Carrington Transit Circle; and the first five years of its use were given, as far as star-observing was concerned, to the observations of a large number of stars between the fifth and seventh magnitudes. In 1867 a new working list of stars was prepared, including all the stars in the British Association Catalogue which still required to be oberved, together with others between the sixth and eighth magnitudes found in various Catalogues, chiefly included in celestial zones from 50° to 70° N.P.D. Mr. Main intended to form a Third Radcliffe Catalogue from observations of nearly 4,400 stars made during the nine years ending in 1870; this laborious work was commenced in 1876, but he did not live to complete it.

With regard to planetary meridional observations, Mr. Main

thought it useful to observe continuously the Sun, and the Moon when she passed the meridian before or very soon after midnight, it being too great a tax on the strength of the Observatory to carry the latter on beyond this. During his first years at Oxford he kept up at certain times meridian observations of all the large and some of the small planets; but afterwards he retained only amongst the former the inferior planets, especially *Mercury*, which the shortness of its period and the frequent difficulty of seeing made it more desirable to observe whenever practicable, and of which many valuable observations were made on days when it was not seen elsewhere.

For details of the cometary and phenomenal observations of various kinds out of the meridian we must refer to the printed volumes of *Observations*. The heliometer was employed in measurements of distances of double stars (especially Struve's *Lucidæ*), of planetary diameters, &c.; by far the greatest part of these were made by Mr. Main himself. A series of observations with it, accompanied by delineations, of spots seen on the Sun commenced to be made in the month of November 1874; these, which were chiefly made by one of his assistants, are printed and engraved in the volume for 1875, the last which Mr. Main published, the date of its Introduction being December 14, 1877. His death occurred on May 9, 1878.

Enough has been said to show that the *Radcliffe Observations* have contributed to the general progress of astronomy. The reductions were carefully and rigorously kept up, and in their methods sundry improvements, particularly in the calculation of the occultations, were introduced. Meteorological observations were also regularly carried on; but his multifarious observatory duties by no means exhausted Mr. Main's energies or scientific activity. He published in 1863 a book entitled "Practical and Spherical Astronomy for the use chiefly of Students in the Universities." This work is referred to in the Annual Report of the Council for 1864 as follows: "It is nothing more than an act of simple justice to the merits of Mr. Main's volume to say that it is the first successful attempt in this country to furnish the student not only with the mathematical deductions of astronomical formulæ, but at the same time with the best methods of their practical application in the actual business of an Observatory." Previously to the appearance of this important work, Mr. Main had published a translation of the first part of Brünnow's *Lehrbuch der Sphärischen Astronomie*, which includes the chapters on Parallax, Refraction, Precession, and Nutation, and which, from its acknowledged excellence, he considered might be of service at Cambridge and other Universities in which the mathematical sciences are cultivated.

Mr. Main was elected a Fellow of the Royal Society in 1860, and served for several years on its Council. His last communication to our Society was, we believe, a paper containing observations of the remarkable meteoric shower in November 1866.

Mr. Main's studies were not at all confined to astronomy. He was a most diligent student during his boyhood and during the whole of his life, and consequently his attainments were very varied. In a biography already published in a church periodical called the *National Church*, we are told that his *Modern Philosophic Scepticism Examined*—an elaborate address delivered at the request of the Victoria Institute, at their ninth annual meeting—passed through many editions. Mr. Main was selected to preach before the British Association at Bristol in 1875; and, on leaving Greenwich, he published a volume of sermons (which he had preached while residing there).

His acquaintance with Latin and Greek was sufficient to enable him to derive a pleasure from reading in those ancient languages which throughout his life he frequently indulged. Of modern languages his knowledge was more extensive than that of most scholars of his time. He could read and translate fluently French, Italian, German, Dutch, Spanish, Portuguese, Danish, and Swedish; and this was of immense service to him by enabling him to read the works of foreign astronomers. In 1838 he married the sister of the Rev. Professor Kelland, who was Senior Wrangler in 1834, and has left three sons—Robert, of the Admiralty; Philip, Fellow of St. John's College, Cambridge, who was Sixth Wrangler in 1862; and Francis, M.A., of the Inner Temple. His only surviving brother is the Rev. Thomas J. Main, who was Senior Wrangler in 1838, and for many years head of the Royal Naval College, Portsmouth.

JOHN MATHESON was born in Glasgow on the 6th of October 1817. Having completed his education, he proceeded to qualify himself for a commercial life, serving for this purpose with the firm of John Matheson & Co., of which his father was the principal partner. Subsequently he obtained an appointment in the house of William Stirling & Sons, turkey-red dyers, one of the most extensive establishments in the country engaged in that important branch of industry. In this new sphere of exertion he soon exhibited great ability and energy, united with rare business talents, and the result was that, after the lapse of a few years, he attained the position of managing partner, and ultimately became the sole proprietor of the establishment. In 1859 he married Miss Jessie Merry Forrester, daughter of the late Robert Forrester, Esq., of Glasgow.

The career of Mr. Matheson outside the calls of business was distinguished by untiring activity. Although he studiously abstained from taking part in the municipal affairs of his native city, he exhibited a deep interest in public questions, and in every movement having for its object the advancement of the material or social condition of the community amidst which he lived. He spoke and wrote with uncommon clearness and vigour, and the results of a sound discriminating judgment were

apparent in all his thoughts. He acted for several years as Chairman of the Glasgow Chamber of Commerce, and the opinions expressed by him, based as they were upon enlarged and judicious views of the commerce of the country, were always listened to with deference.

While Mr. Matheson took a leading part in all social and philanthropic movements connected with Glasgow, he was at the same time distinguished by a considerable degree of mental culture. In early life he contributed occasionally to the periodical literature of the day. During the latter period of his career he visited India twice, chiefly with the view of acquiring additional knowledge respecting the commerce of that great country, with which he carried on extensive mercantile transactions; and the results of his observations on the occasion of his first visit were published in a work entitled "England to Delhi," which contains much interesting information and picturesque description conveyed in a pleasing style. Mr. Matheson exhibited a deep interest in astronomical studies. He was elected a Fellow of the Royal Astronomical Society in the year 1866. In 1876, when the British Association met at Glasgow, he communicated to the Association a valuable paper on the silver currency, a branch of a subject to which he had devoted much attention. He was President of the Athenæum, a literary and educational Institution of Glasgow, and at the time of his death he was preparing a lecture which he purposed delivering to its members at the commencement of the winter session. He frequently delivered popular lectures on various subjects to the working people of his establishment, which was situated in the Vale of Leven, about twenty miles from Glasgow.

His last public appearance in Glasgow was in connection with a great commercial disaster which had befallen his country, and his friends love to think that he was on that occasion permitted to give one more practical proof of the noble generosity of his nature. His death occurred under circumstances especially painful. He was Chairman of the Glasgow Festival Concerts Committee, and on the evening of November 12, 1878, he was to have presided at the commencement of a series of concerts given by the Glasgow Choral Union, but as he was proceeding from his office to his private house on the same day he was taken ill in one of the thoroughfares of the city, and instantly expired.

Mr. Matheson was endowed with a genial warmth of disposition and a hearty kindliness of manner which endeared him especially to those who had the privilege of his personal acquaintance. His career was one of unceasing public usefulness, and his loss was deplored by multitudes of all classes of society in Glasgow and the Vale of Leven, who retain a lasting remembrance of the many admirable qualities of head and heart by which he was distinguished.

JOHN WALTER NICHOL was admitted a Fellow of this Society on the 8th of May 1874. He was born at Edinburgh on January 29, 1843. He was the son of Walter Nichol, Doctor of Laws, Teacher of Mathematics in the High School, Edinburgh. Mr. Nichol received his earlier education at the Edinburgh Institution, and subsequently attended lectures at the University of that city. On quitting the University, Mr. Nichol entered the office of a firm of merchants in Leith, in which he remained till he acquired considerable knowledge of mercantile business.

His mind led him to the study of scientific subjects, and specially to that of astronomy; and as he happily had the means available to gratify this taste, he spared neither time nor effort in trying to attain proficiency.

At the close of his curriculum he was engaged by Professor P. Smyth to assist in the reduction of the Edinburgh observations which form the basis of the Catalogue of stars recently published there. Mr. Nichol volunteered his services for the observation of the transit of *Venus* 1874, and accompanied the expedition to the Hawaiian Islands, under Captain Tupman, greatly contributing to the success of the enterprise by his accurate, business-like habits. On returning to England he was entrusted with the reduction of the lunar and meridional observations made at Honolulu; on completing which he proceeded to Germany, and studied his favourite science under Professor Bruhns, of Leipzig, for two years, publishing (*Astron. Nach.* No. 2211), while there, an investigation of the orbit of the third comet of 1877 from the whole of the European observations.

Returning to England, he was suddenly cut off in the prime of life by a pulmonary affection, and died at Teignmouth on November 4, 1878.

His genial and kindly nature, combined with his excessive *bonhomie*, rendered him a pleasant friend, and many of the associates of his earlier youth remember the good, true, and frank spirit with which he was wont to enliven their frequent reunions.

GEORGE GRANADO GRAHAM FOSTER PIGOTT, eldest son of the Rev. George Granado Graham Foster Pigott, Rector of Abington Pigotts, Cambridgeshire, was born on May 16, 1835. He was educated at Marlborough College, and served in the Cambridgeshire Militia in 1854. He entered the 48th Foot as ensign in April 1855, and was present with his regiment at the fall of Sebastopol in September of that year. He served with his regiment during part of the Indian Mutiny, and retired from the Army in November 1859. He devoted much time to meteorological pursuits at his native place, Abington Pigotts, till his death, which took place on May 14, 1878. He was elected a Fellow of the Royal Astronomical Society on June 9, 1865. He was a Fellow of the Meteorological Society.

GEORGE VENABLES VERNON was the only son of Mr. John Venables Vernon, of the firm of Vernon and Edge, engravers to calico printers, David Street, Manchester, and was born on October 7. 1831. He went to a school kept by a Mr. Williamson, of Stretford Road, Manchester, and afterwards studied for some years under a private tutor. He had a great liking for scientific pursuits generally, but more especially for meteorology. He was elected a Fellow of the Royal Astronomical Society on January 14, 1853, and in 1861 was elected a member of the Manchester Literary and Philosophical Society. He contributed many papers, chiefly on meteorological subjects, to the *Proceedings* and *Memoirs* of the latter society, and was for several years secretary of its physical and mathematical section. When Mr. Glaisher was organising, in 1848, the system of meteorological observations at different stations over the country, the results of which are published in the Registrar General's Reports, Mr. Vernon expressed his willingness to become an observer, and his observations were made and published regularly from 1849 till nearly the date of his death. He was a Fellow of the Meteorological Society and of the Anthropological Society, and a member of the Meteorological Societies of Scotland and France. He carried on the business of a cotton spinner. In private life Mr. Vernon was genial and kind-hearted, and he was very fond of music and other accomplishments. He had a severe illness—an attack of congestion of the brain—a year or two before his death, from the effects of which he never wholly recovered; he suffered much during the last year of his life, and died suddenly of heart disease on January 11, 1878. He leaves a widow.

ANGELO SECCHI was born at Emilia, Reggio, on June 29, 1818. He attended the school of the Jesuit College of the district, where he was grounded in Greek and Latin.

At the age of 15 years he entered the Company of Jesus, and after terminating his noviciate at the Collegio Romano, he lectured for a year in Rome on grammar and the rudiments of philology; after which he was sent by his superiors to conduct the classes of physics and mathematics in the College at Loretto, where he distinguished himself by his concise and clear method of teaching.

In 1844 he commenced his theological studies preparatory to entering the Church, and continued these without interruption until he was ordained priest on September 12, 1847.

He remained in Rome, lecturing at the Collegio Romano, till March 1848, when political disturbances having arisen in Italy, he was forced, with the rest of his order, to quit his home and go into exile. With many others he came to England and was sent to the Roman Catholic College at Stonyhurst, where, having nothing better to do, he devoted himself to the study of mathematics, until, on October 24, 1848, with twenty-one of his

companions in misfortune, he sailed from Liverpool, arriving at New York on November 19; thence he proceeded to the Georgetown University near Washington, where, while teaching the elements of natural science, he found time to pursue his favourite studies, working in the College Observatory, then directed by Father Curley.

Professor De Vico having died in London in 1849, Secchi was recalled by the General of the Order to succeed him in the chair of astronomy, and to direct the Observatory of the Collegio Romano.

He left Georgetown on September 21, and came to England, visiting the Royal Observatory, Greenwich, and thence passed on to Paris, re-establishing the broken communications between the Observatories.

He had been but a short time in his new position when he set about the foundation of a new Observatory in the Collegio Romano.

Departing from usual principles, he placed his instruments on the top of one of the massive piers which support the dome of the Church of Sant' Ignazio. The new Observatory was formally opened in 1852, and was speedily provided with an excellent refractor by Merz and a fine sidereal clock by Dent. Aided by the munificence of His Holiness the Pope, he established in the same place a very complete Magnetical Observatory. In the course of his meteorological studies he was led to the construction of his celebrated Meteorograph, an instrument by which automatic registrations of the barometer, thermometer, winds, and rain are made at short intervals of time. One of these was sent to the Paris Exhibition of 1867, and was esteemed so highly that the Emperor Napoleon III. conferred upon Padre Secchi the decoration of the Legion of Honour, and the Emperor of Brazil gave him the Grand Cordon of the Order of the Rose.

Probably Secchi's greatest work was the division of stellar spectra into four great groups or classes, viz.:—

Type 1. In which the hydrogen lines are very marked. To this group belong *Sirius*, *Vega*, *Altair*, *Regulus*, and *Rigel*, and about half the stars in the heavens.

Type 2. In which there are numerous fine dark lines, as in the spectrum of our own Sun, and in *Pollux*, *Arcturus*, *Aldébaran*, *Procyon*, and *α Ursæ Majoris*.

Type 3. In which the spectrum is divided by a system of nebulous bands, which are rather more definite towards the violet end, as, for example, in the spectrum of *α Herculis*.

Type 4. In which the spectrum is divided by broad nebulous bands, very definitely defined on the less refrangible side. To this group belong many of the small deep red stars.

Secchi was the first to point out the characteristic features of these groups. He gave considerable labour to examining and classifying stellar spectra, and published numerous catalogues and lists of star spectra, two of the most important of which are

Catalogo delle stelle di cui si è determinato lo spettro luminoso, published at Paris in 8vo. in 1867, and *Sugli spettri Prismatici delle Stelle Fisse*, published in Rome in 8vo. in 1868.

Secchi published regularly the *Memoria dell' Osservatorio*, and these were supplemented by the *Bulletino meteorologico dell' Osservatorio del Collegio Romano.*

He was employed by the Papal Government in 1854 to execute the measurement of a base line, a full description of which appears in his Memoir, *Sulla Mesura della base Trigonometrica eseguita sulla Via Appia nel* 1854–5.

He was also commissioned by his Government to design and superintend the erection of the lighthouses on the coasts of the States of the Church, and at another time the schemes for the water supply of several Roman towns were confided to his skill and judgment.

In 1860 he was sent to Spain for the observation of the Eclipse of the Sun on July 18. Working in conjunction with Señor Aquilar, of Madrid, he was fortunate enough to obtain four photographs of the corona during the total phase.

In 1862 he proceeded to Paris, where he represented his Government at the International Commission on the Metric System.

On September 20, 1870, with the entrance of the Italian troops into Rome, the Papal civil dominion passed away.

The decrees of the new Government against the Church are a matter of history upon which it is not necessary here to dwell; but it will ever be to the honour of the Administration that arrangements were made by special Acts of Parliament to enable our illustrious Associate to continue to occupy the Observatory, which, under his control, had attained a worldwide fame.

In December of the same year he was sent to Augusta, in Sicily, to observe the Solar Eclipse of December 20.

Early in his scientific career the various great Societies recognised his works and placed his name on the list of their Foreign Associates.

The Royal Society elected him November 20, 1856. He became Associate of our Society in June 1853, and he was also Member of the French Académie des Sciences, and of the Imperial Academy of St. Petersburg.

In Italy he was one of the Società Italiana de XL., and was for some years President of the Accademia dei Nuovi Lincei.

The last few years of his life, feeling that his vital power was slowly ebbing, he abandoned active observations, and devoted himself to study, though always controlling and directing the researches of his valued and indefatigable assistants.

Space forbids the rehearsal of the titles of all Secchi's writings. Up to the year 1863 upwards of 200 Memoirs and papers were contributed by him to various scientific bodies and to journals with which he corresponded.

His larger works, which may be mentioned, are the "Measure-

ment of the Base Line on the Via Appia," to which we have already referred, and

1. *Il Quadro fisico del Sistema Solare.*
2. *L'unità delle forze fisiche*, a work which has gone through two Italian editions and has been translated into French and German.
3. *Le Soleil.* Two French editions; also translated by Schellen into German.
4. *Elementi di Astronomia* (lithographed for the use of his students).
6. *Le Stelle.*
7. *Lezioni di Fisica Terrestre* (for the young).

A month before his death appeared, at Milan, *Le Stelle*, which forms one of a valuable series of Popular Science volumes.

In this work he sums up his work on the Physical Constitution of the Stars, to which he had devoted so great a portion of his career. His last work, *Lezioni di Fisiça pei Giovani*, is now in the press.

Early in January 1878 illness forced him to take to the bed from which he was fated never to arise.

Though aided by the first surgeons of the University, science was unable to cope with nature, and terrible disease terminated, at the age of only 59 years and three months, a career which had shed lustre on his country and had added another to the long list of names of which the Jesuits are so justly proud.

Proceedings of Observatories.

The following Reports of the proceedings of Observatories during the past year have been received by the Council from the Directors of the several Observatories.

Royal Observatory, Greenwich.

Observations of the Sun, Moon, and planets with the Transit Circle, and of the Moon with the Altazimuth, have been made regularly as in past years. Considerable progress has been made in the observation of stars in the working list, and the Annual Catalogue for 1878 is larger than usual, containing about 1,300 stars.

A considerable number of observations of phenomena of *Jupiter's* satellites have been accumulated during the past year, and occultations of stars by the Moon have been observed whenever the state of the sky permitted.

The printing of the *Nine-Year Catalogue of 2,263 Stars* was completed last summer and the Catalogue is ready for distribution; but before issuing it to the public, it appeared desirable to compare it in N.P.D. with the two last preceding Catalogues. In the Nine-Year Catalogue a change has been made in three of the elements of reduction, viz. the R – D correction, the mean refractions, and the co-latitude, and the comparison with the two Seven-Year Catalogues shows large systematic differences depending mainly on the diminution of refractions and consequent alteration of co-latitude, introduced at the beginning of 1868. The discussion is not yet finished; but the observations of the Sun at the solstices, and of circumpolar stars, and the comparison of the Cape and Melbourne Catalogues with the First Seven-Year Catalogue made by Mr. Downing, seem to show that the old refractions are sensibly correct and that the N.P.D's. of the Nine-Year Catalogue will require systematic correction. It is proposed to insert this discussion as an appendix to the Introduction, and the issue of the Catalogue has consequently been delayed for a short time.

The spectroscopic work has been interrupted since last May, in order that the reductions of the measures of photographs of the Sun might be pushed forward. The chromosphere was examined on 34 days, on 15 of which no prominences were seen; the search, however, was made under somewhat unfavourable circumstances on 10 of these days. The solar spectrum in the neighbourhood of G has been repeatedly examined

with reference to the existence of bright lines in that region, and on May 31 several photographs of this part of the spectrum were taken. The results have been communicated to the Society. The spectroscopic determination of star motions in the line of sight has been continued, and measures of the displacement of the lines of hydrogen or magnesium in the spectra of 34 stars have been made; 11 of these had not been previously examined. All of these observations were made with the Half-prism Spectroscope. The spectrum of the eclipsed Moon was examined with the Single-prism Spectroscope on 1878, August 12, and observations of the "rainband" in the sky spectrum were made daily up to June last with a small Half-prism Spectroscope.

During the year 1878 photographs of the Sun were taken on 146 days; on only 29 of these were any spots visible, and on only 44 days groups of faculæ. There has been a marked diminution in the numbers of spots and faculæ as compared with the previous year. The arrears of photographic reductions, which had accumulated since 1873 in consequence of the delay in the construction of the Position Micrometer have now been cleared off. The position angles and distances of spots and faculæ from the Sun's centre, as well as the areas, have been measured in duplicate up to the present time, and the heliographic latitudes and longitudes, and areas in millionths of the Sun's visible hemisphere, have been deduced from them. The copy for press has been prepared, and the complete results for the year 1876 have been printed in the volume of *Greenwich Observations* about to be issued, leaving the results for the years 1874, 1875, 1877, and 1878 to be included in the next volume. The areas as distinct from positions had been already printed for 1874 and 1875 in the corresponding volumes of *Greenwich Observations*.

The serious and prolonged illness of Mr. Lynn has caused a severe pressure on the Observatory during the last ten months, and it has been found necessary to have frequent recourse to the assistance of computers for the ordinary observations. The reductions, however, have not been suffered to fall behind, and they are now in a very forward state. The unusually cloudy weather of the last two months (succeeding a remarkably fine autumn) has materially relieved the pressure on the computing staff. All the current reductions are brought up to the present time, and the Star Ledgers of R.A. and N.P.D. for 1878 are formed.

Astronomers are well aware of the extent and accuracy of the meridional observations in general and of the meridional and extrameridional observations of the Moon in particular, most regularly followed up at the Royal Observatory, and printed in detail in its *Observations*. But they are scarcely aware that the same volumes contain a great mass of separate essays on various trains of observation and other

subjects relating to astronomy, which it is hoped are not without value. The Astronomer Royal has commenced the formation of an Index to these essays, which may bring them more to the notice of the public, and may render them at once accessible to the astronomer's quest.

The Radcliffe Observatory, Oxford.

In May last this Observatory was deprived by death of the services of its eminent and distinguished Director, the Rev. Robert Main.

The Trustees of the institution shortly afterwards placed it under my* temporary control, pending their appointment of a successor to Mr. Main. By a somewhat recent statute of the University, the Savilian Professor of Astronomy is no longer permitted to hold the directorship of the Radcliffe Observatory.

By a remarkable concurrence of events, the second assistant of the Observatory died very soon after his respected chief, and at the same time the first assistant, Mr. Lucas, on account of the infirm state of his health, retired from his office with a handsome pension accorded to him by the Trustees in acknowledgment of his long services. There remained, therefore, on the staff of the Observatory one assistant and one computor only. These, however, have been temporarily supplemented by assistance derived from the resources of the University Observatory.

Mr. Stone, the Director of the Royal Observatory at the Cape of Good Hope, has been appointed to the Radcliffe Observatory, and is expected to arrive in Oxford early in July of the present year. The Radcliffe Trustees, with great liberality and consideration, have allowed Mr. Stone to remain in his present post at the Cape until he shall have satisfactorily completed the great work of a Catalogue of Southern Stars, which for some years past has occupied his attention.

At the suggestion of the Trustees I submitted to the Astronomer Royal and to Professor Adams propositions for the reorganisation of the Observatory, and I am gratified at finding these propositions have met with the approval of these eminently practical authorities. Mr. Stone also has expressed his acquiescence in the plans suggested.

Exactly the same sort of work, and on the same lines as that adopted by Mr. Main, has been carried on at the Observatory so far as the more limited staff has permitted; my chief endeavour being to leave Mr. Stone unfettered in the making of his own arrangements, and in the establishing of his own traditions, and as unincumbered as possible by the accumulation of arrears.

* The above report is written by Professor Pritchard.

The state of the Carrington Transit Circle has occupied much of my anxious attention. From its first erection in Oxford it has been affected with an uncertainty in the determination of the nadir to a far more serious extent than is usual and unavoidable with first-class astronomical instruments. Notwithstanding numerous experiments and devices, I have been unable to ascertain the cause or causes of the discrepancy in question. The instrument had been used for a considerable time by Mr. Carrington at Red Hill. It was transferred from thence to Oxford, and erected in its present position, without the assistance of a professional instrument maker, and it is quite possible that it may have been slightly injured during the removal, or that the brass plates which support the pivots of the instrument may have been insecurely attached to the piers. No doubt it will receive Mr. Stone's earliest attention, and if found to be either too small for present requirements or otherwise inherently defective, the Trustees will probably supply a new and superior instrument.

Oxford University Observatory.

Since the date of the last annual report of this Observatory, the delegates of the Clarendon Press have printed and circulated the first fasciculus of the astronomical observations made here under my direction. I take this opportunity of thanking the many eminent astronomers, both at home and abroad, for the hearty sympathy and encouragement which they have accorded to this first contribution made to the extension of astronomical science in this new institution of the University of Oxford.

In accordance with a remark made in the last annual report, the observation of double stars has been exclusively confined to objects whose well pronounced relative motions and other circumstances present the promise of an accurate determination of their elliptical orbits. A comparison of the observed motions of the components of ξ *Ursæ Majoris*, 70 *Ophiuchi*, μ^2 *Boötis* with those derived from the orbits computed in this Observatory turns out to be highly satisfactory, and more particularly so in the case of ξ *Ursæ*, where the rapid change of positional angle affords a rapid and secure test of the accuracy of the theoretical work.

In the course of the preceding and present winters two sets of measures of 40 of the stars in the *Pleiades* have been completed, and their remeasurements will be continued so long as the stars remain visible during the present apparition of the group. They are with the *duplex micrometer* attached to Mr. Grubb's Refractor. When these observations have been reduced they will be compared with Bessel's celebrated measures of the same stars made with the Königsberg Heliometer in 1838.

A few observations of Tempel's periodical comet have been secured, notwithstanding its low altitude and the brightness of the sky at the time of its apparition. No other observations of this periodical comet appear to have been published in England.

Lunar photography has been prosecuted with the same regularity as heretofore. Mr. De La Rue's magnificent measuring engine arrived at the Observatory in the course of the spring; no time was lost in ascertaining its capabilities, and those of the lunar photographs to the purposes of delicate and accurate measurements, and their applicability to the practical determination of the lunar physical libration. The preliminary examination has occupied much time; but at the present a fair amount of progress has been made in the determination of the selenographical coordinates of Triesnecker (B) and Ptolemy (A); these being the two points selected for the prosecution of this laborious and intricate investigation. In the course of this preliminary work, it seemed that an excellent subsidiary test of the general accuracy of the instrument and of the photographs might be afforded by ascertaining how far both of them were applicable to the determination of the height of lunar formations. The result has been highly satisfactory. The peculiarity of the measuring instrument, and the quiescent nature of a photograph, enables us to dispense with the troublesome and inaccurate reference to the Moon's terminator, and even the lunar cusps, at all times ill defined. The success of this presumably new application of celestial photography affords some substantial hope of still further usefulness of the process.

The intelligent and diligent attention of the two assistants, Mr. Plummer and Mr. Jenkins, to their varied duties in this Observatory demands acknowledgment.

The sub-aerial observatory, completed on the roof of the new lecture room, attracts the curiosity of many of the University students. An instrument for measuring and recording the daily amount of sunshine is placed among the other instruments, and the results are published weekly in an Oxford journal. It excites considerable interest; and if similar records were kept in various districts throughout the country, some important information might be reasonably expected.

Cambridge Observatory, 1878.

The work carried on during this year continues to be of the same character as that of several previous years. A large proportion of the zone stars have now been observed three times and upwards, so that in certain regions it has become requisite to increase the working breadth of the zone, and even with this

advantage the progress of the work is occasionally somewhat slow; the weather, too, has been unfavourable. But, notwithstanding these drawbacks, 3,065 observations of zone stars have been made during the year, and 671 observations of standard stars for clock and instrumental correction, with the necessary observations for collimation and level errors and for nadir points.

The reductions of standard stars are finished up to the end of 1877, both for Right Ascension and North Polar Distance: the reductions for 1878 are in progress. The calculation of the constants used in the reduction of zone stars is completed for 1875 and is well advanced for 1876. The mean Right Ascensions and North Polar Distances of zone stars are computed to the end of 1874, the true Right Ascensions and North Polar Distances to the end of 1875. All the observations up to the present time are entered in the reduction books, and the means of microscopes and wires taken. The Declination Micrometer has been carefully tested, by bisecting the wires in the South Collimating Telescope, and it has been shown conclusively that it is a matter of indifference whether a star is bisected by moving the wires towards the micrometer head or in the opposite direction.

It had been found that the nadir point was sensibly affected by the unequal expansion of the telescope tube caused by heat from the observer's body; it has been judged necessary, therefore, to protect the tube by a quilted calico covering from sudden changes of temperature due to this cause.

It is thought probable that the discrepancies between the results of direct and reflected observations, known as the "Discordances of Zenith Points," are mainly occasioned by these unequal expansions of the telescope tube, but that they are also in part due to inequality in the refractions suffered by the direct and reflected rays in their respective passages from the external air to the observer's eye.

In order to throw light on the latter point several good standard thermometers have been procured and experiments with them are in progress for comparing from time to time the temperatures in different parts of the transit room with that of the external air.

Dunsink.

The South Equatoreal has been employed in observations of annual parallax. A series of differences of declination between 61 *Cygni* and a neighbouring star was completed and shows a parallax of 0″·4654. A set of measures of the distance and position from Groombridge 1618 to an adjacent star will be completed in March, and systematic observations of two other stars have been commenced. Measurements of a large number of other stars have

been made, with the view of selecting those which will be suitable for regular parallax observations.

Mr. Burton having resigned on account of ill-health, Mr. Dreyer took charge of the Meridian Circle at the end of last August.

The observations of red stars, which, for various reasons, had not made much progress for some time, form this winter the only object of observation, and will, it is hoped, be finished in the coming summer. When the resulting positions of red stars have been brought out in the course of next winter in Part IV. of the *Dunsink Observations*, it is intended to devote the Meridian Circle to a longer series of observations of stars with large proper motion.

Royal Observatory, Edinburgh.

At the Royal Observatory, Edinburgh, the work has consisted nearly as usual in time observations, daily time signals by ball and gun, and control of public clocks; also in the extensive meteorological computations required by the Registrar-General for Scotland to illustrate the climates of fifty-five observing stations spread over the whole of North Britain.

The Assistant Astronomers, Mr. Alexander Wallace, M.A., and Mr. Thomas Heath, B.A., have further done good work in perfecting the MS. of additional portions of the Star Catalogue to what was contained in vol. xiv. of the *Edinburgh Astronomical Observations*. And the Astronomer has succeeded in observing carefully the whole solar spectrum, by eye and glass transmission, to an extent of 2,200 micrometer measured lines, or about 1,000 more than what are contained in Angstrom's excellent *Normal Solar Spectrum Map*. Most of these additional lines are far too faint to be of much importance; but an occasional strong case of anomaly has been found which must signify either an accidental error in Angstrom or a variation in the quality of solar radiation with time. In preparation for the possibility of something of the latter kind eventuating, this Edinburgh Solar Spectrum has been entitled as "for the *epoch* 1878.'

The Edinburgh Royal Observatory hopes to have the power of printing its observations restored to it before long, as well as that something may at last be done for strengthening the establishment in the directions pointed out by both the Commission of Enquiry two years ago, and the many persevering annual reports of the Edinburgh, Government appointed, Board of Visitors.

Kew Observatory.

The astronomical work of this Observatory has been confined during the past year to the continued measurements of the Sun-pictures taken during the years 1862-71, which has been carried on at Mr. De la Rue's expense and under his direction.

On account of the large number of spots which appeared on the Sun's disk during the years 1870 and 1871, it has not been found possible to complete the whole series of pictures, but measurements have been made up to the end of February 1872, and it is contemplated that another month will suffice for finishing this branch of the work, as the Kew series ends on April 9, 1872.

The reduction of the measurements to heliocentric elements has been continued by Mr. Marth for Mr. De la Rue.

The eye observations of the Sun after the method of Heinrich Schwabe have been made daily, when possible, in order for the present to maintain the continuity of the Kew record of Sun-spots.

The question of observing solar radiation having been referred by the Meteorological Council to the Kew Committee, a sub-committee has been appointed to take the whole subject into consideration.

The Campbell Sundial continues in action, and the improved form of the instrument, giving a separate record for every day of the duration of sunshine, has been regularly worked throughout the year and its curves tabulated.

The magnetical and meteorological work, to which the attention of the Observatory is chiefly directed, has been prosecuted continuously, and the Verification Department has been fully occupied the whole year.

Liverpool Observatory, Bidston, Birkenhead.

The general work at this Observatory during the past twelve months has differed but little from that of preceding years.

A large amount of information is now being collected with regard to the performance of chronometers at sea.

Probably but few persons are aware of the degree of accuracy which may be attained in the determination of the longitude of a ship at sea by the application of corrections due to change of temperature to the rates of chronometers. For the last sixty chronometers returned to the Observatory, the average length of voyage is 110 days, and for the best thirty of them, or half of these, the mean error—that is, the difference between the error of

the instrument on Greenwich mean time as found by calculation, by using a variable rate dependent on the temperatures to which the instrument was exposed during the voyage, and the absolute error on Greenwich mean time as found by comparing the instrument with the normal clock at this Observatory—is 9·3 seconds, or under two and a half geographical miles on the Equator after a voyage of nearly four months.

Temple Observatory, Rugby.

The principal work of the Observatory during the year 1878 has been the measurement of position and distance of 65 double stars, a number somewhat less than that of previous years, owing in a great measure to the fact that the attendance of members of the school and the time given to them has been very considerably increased since the Observatory has been built on the present site.

The measurements are chiefly of stars contained in a list made by Mr. Wilson of well ascertained binaries.

Mr. S. has given further attention to the measurements of the motions of recession or approach of stars with the large spectroscope on the reflector, and has taken 23 sets of measures, but the available evenings have been few.

The educational use of the Observatory has during the past year largely increased, 352 names appearing in the note book. We are sorry to have to record the fact of Mr. Wilson's withdrawal from the direction of this Observatory, in consequence of his appointment to the head mastership of Clifton College.

The Temple Observatory will now be under the direction of Mr. Seabroke.

Stonyhurst Observatory.

The astronomical work in this Observatory was considerably interfered with by the absence of the object-glass of the large Equatoreal during the first six months. One of the surfaces of this glass has been reground by Mr. J. Simms, and the definition has thus been considerably improved.

The eclipses of *Jupiter's* satellites were observed with a 9-inch Cassegrain during the polishing of the lens of the Equatoreal; and this Cassegrain and a 4-inch achromatic by Jones were in readiness for the transit of *Mercury* on May 6, had the state of the sky been favourable.

The improvement of the Refractor has caused the double-star work to be undertaken more perseveringly than formerly, and a large spectroscope is now in course of construction for the Observatory, which will be employed principally in daily work on the Sun.

The Director of the Manila Observatory has spent some time at Stonyhurst in the course of the year, and a first-class theodolite and standard astronomical clock are shortly to be sent to his distant station.

A chronometer and dip circle have also been lately tested at this Observatory, previously to being taken out to the South of Central Africa by some missionaries who sailed in January from Southampton.

Mr. Barclay's Observatory.

The principal feature of the past year's work has been the publishing of the fourth volume of the *Leyton Astronomical Observations*. As stated in a previous Report, it is considered best to publish frequently, even if the number of observations be comparatively small, as an accumulation of unreduced observations, which is apt to become overwhelming, is prevented, and observations which may perhaps be useful to others are immediately available.

The instruments remain as before described. The whole of the Equatoreal has this year been dismounted for the purpose of cleaning the various bearings. It has hitherto been found impossible to obtain an oil that does not thicken and become as tenacious as glue.

Colonel Cooper's Observatory, Markree.

During the past year double stars and planets have been systematically observed at this Observatory with a number of different micrometers. With the Munich spider-lines micrometer both angles and distances were measured directly, and the same apparatus was used for oblique transits. With the prismatic double-image micrometer I could only measure distances. With the square-bar micrometer I observed differences of R.A. and Decl.

At present I observe systematically all double stars of between 65° and 85° Decl. north (with the exception of such objects as are positively known to be motionless from previous

investigations). If the observation agrees with the earlier results, I do not examine the object again; but if I find a difference, I continue the measures in order to form a reliable epoch.

The severe frost which occurred at the end of last year interfered a good deal with the working of the large telescope. A couple of nights the tube was so hard to move in R.A. that it took two strong men to alter it, and subsequently the observations had to be given up, the telescope being all covered over with snow and frozen, as was also the yard where it is placed.

Mr. Edward Crossley's Observatory, Bermerside, Halifax.

No important change in the work of this Observatory has taken place since the date of the last Report. Measures of double stars have been made, phenomena of *Jupiter's* satellites observed, and a new micrometer, by Simms, carefully tested; but the principal work of the Observatory has been the compilation of notes on double stars and the collection of measures for the purpose of forming a catalogue of binaries. The new driving clock, by Mr. Grubb, was fixed in July, and has been found both powerful and effective.

Mr. Huggins' Observatory.

During the past year the work of obtaining photographs of the spectra of stars has been pursued whenever the weather has been sufficiently favourable. Considerable progress has been made; but for this work only the finest nights are available. On the occasion of the transit of *Mercury* arrangements were made to obtain a photograph of the spectrum of *Mercury* superposed on the solar spectrum, chiefly to observe if any modifications of the solar spectrum due to an atmosphere were to be found near the limbs of the planet. Unfortunately, the weather was not sufficiently favourable at the time of the transit.

Observatory, Birr Castle.

During the earlier part of the year 1878 the observations were carried on as usual at the Observatory of Birr Castle, but work was not resumed at the telescopes after the short nights of the summer solstice. My assistant, Mr. J. Dreyer, left for

Dunsink towards the end of August, the preparation of Part II. of *Observations of Nebulæ* having been completed for sending into the Royal Dublin Society, and the observations for Part III., which completes the work, having been carried on as long as was deemed necessary before closing the series.

As I was leaving home in July last, with little hope of returning to reside there for a year or more, I was unable to take steps for engaging in any new line of work, and except for taking the 9 A.M. and 9 P.M. meteorological readings, the Observatory remains closed for the present.

The 12·45 P.M. G.M.T. "Synchronous" meteorological observations have been discontinued.

Colonel Tomline's Observatory, Orwell Park.

The past year having been on the whole unfavourable to equatoreal observation, the opportunity has been taken to complete the reduction of arrears of all kinds. The cometary observations of 1877 have been fully reduced and the results have been sent to the Editor of the *Astronomische Nachrichten* for publication in that journal.

The longitude of the Observatory has been determined by the method of the Moon and culminators, and the result, $4^m\ 57^s{\cdot}75$ E., exceeds by nearly two seconds that inferred from the Ordnance Survey. This result is scarcely definitive, as other observations exist for which the corresponding ones at Greenwich are not yet published; but, depending as it does on an equal number of observations (11) of either limb of the Moon, it is not anticipated that any sensible alteration will require to be made.

A great number of transit observations of stars have likewise been reduced, which are expected to yield some interesting results bearing on proper motion.

Tempel's comet has been looked for on several occasions, but, owing to persistent cloud and haziness near the horizon, has not been seen. The like ill success in the case of Swift's comet is explained by the unfortunate misinterpretation of the telegram announcing its discovery.

The transit of *Mercury* on May 6 was very fairly observed, and afforded gratifying proof of the excellence of definition of the object glass.

It was found necessary in September to dismount the telescope in consequence of some particles of rust having found their way into the bearing of the declination axis, almost entirely preventing the movement. The rust was removed by Mr. Simms, and since that time the working of the instrument has been quite satisfactory.

Royal Observatory, Cape of Good Hope.

The reobservation of the stars in Lacaille's zones is finished. All the reductions are completed, and 9,000 stars are accurately reduced to epoch, and have their precessions and secular variations computed and examined. The rest of the observations are very approximately reduced to epoch, and the computation of the precessions and secular variations is being pressed forward as rapidly as possible. We are now only observing stars to fill up a few *lacunæ* which have been detected on projecting our places on a large scale chart for that purpose.

The Catalogue will probably be completely finished before Mr. Stone leaves the Cape in the middle of June, and it will contain about 13,000 stars. Mr. Stone intends to bring the work home to be printed, as the printing at the Cape would take two years.

The volume for 1876 has long been finished and is now nearly printed. The printing has been delayed to pass through the press the Catalogue for 1860, which will be bound up with the 1876 volume as an appendix.

Melbourne Observatory.

During the past year the meridian observation at this Observatory has been somewhat relaxed in order to give more time for the reduction of the zone observations between the parallels 150° and 160° N.P.D., and it has therefore been chiefly confined to the routine observations of fundamental clock and circumpolar stars. In November, however, a series of observations was made for the determination of the R.A. of certain stars selected by Mr. Gill to enable him to investigate certain systematic errors in the Right Ascensions of the *Mars* comparison stars as determined at various Observatories.

The Great Telescope continues in good working order, and has been devoted steadily to the revision of Sir John Herschel's figured nebulæ. Nos. 4223 and 1561 of the General Catalogue, widely separated from each other, and described by Herschel as prominent objects, cannot now be found. The nebula around *η Argûs* was carefully compared with the drawings of March 1876; the only change which has been clearly established since that date is a break or separation in one of the branches on the preceding side. Among other work the Trifid Nebula has occupied some attention, and the drawing, which, however, is not yet quite complete in all its details, agrees fairly with Mr. Lassell's drawing of 1862, the three principal stars near the centre being unmistakably involved in the nebula.

The drawings of all the nebulæ made at the Great Telescope, although lithographed, have not yet been published, owing to unforeseen delays in the Government printing departments.

The 8-inch Refractor has been employed partly in planetary observation, but principally on southern double stars, in continuation of a revision of Sir John Herschel's list.

Sun-pictures have been obtained every day with the photo-heliograph, and the absence of sun-spots during the year has been very remarkable.

The usual meteorological and magnetical work has been carried on uninterruptedly.

The transit of *Mercury*, which took place on May 7, had passed through its earlier phases before the Sun rose above the Melbourne horizon; the latter phases, however, were all observed and the results have appeared in the *Astronomical Notices*.

The only astronomical publication issued during the year was a pamphlet containing the observations of *Mars* and comparison stars at the opposition of 1877.

The meteorological publications issued are the *Monthly Records of Meteorology and Terrestrial Magnetism* and the *Meteorological Results for the year* 1876.

The establishment and instrumental appliances are in an excellent and effective condition; it is proposed, however, to replace the present Transit Circle, which has a telescope of 5 inches aperture, with one similar to that at Cambridge (England), which has an objective of 8 inches diameter, and the Colonial Government has already testified its readiness to furnish the requisite funds.

NOTES ON SOME POINTS CONNECTED WITH THE PROGRESS OF ASTRONOMY DURING THE PAST YEAR.

Professor Newcomb's Researches on the Moon's Motion.

For several years Professor Simon Newcomb has been engaged on some important researches on the motion of the Moon. As originally planned by him, the work was divided into two portions; I. the mathematical theory of the inequalities of long period in the Moon's mean motion; and II. the reduction and discussion of the observations of the Moon made prior to 1750. With the aid of a grant from Congress these two portions were carried on simultaneously, with the intention of completing them in the above order. But when the mathematical investigation was supposed to be brought nearly to a close, it was found that certain terms which were at first supposed to be of no importance would have to be investigated, and that this investigation might prove the most tedious part of the whole work unless some method of shortening it could be devised. Professor Newcomb has not yet been able to decide which is the best method of treating the subject; the investigation is still incomplete; so the portion intended as Part II. has been issued as Part I. of these researches.

In the last Report of the Council an account is given of the principal results which have been deduced from his researches by Professor Newcomb. The full details of these researches are now published, and form Appendix II. to the *Washington Observations* for 1875. The volume contains a full account of the reduction and preliminary discussion of the observations of the Moon made before 1750. Professor Newcomb critically examines all the ancient eclipses of the Sun, but rejects them as being too uncertain to afford trustworthy data. From the eclipses of the Moon quoted by Ptolemy, Professor Newcomb deduces the correction to the places of the Moon at the four early epochs B.C. 687, 381, and 189, and A.D. 134. By reducing the observations of the eclipses observed by the Arabian astronomers during the ninth and tenth centuries, Professor Newcomb deduces the errors of Hansen's tables for the epochs A.D. 850, 927, and 986. A few of these observations are found to be discordant with the rest and two to be irreconcilable with theory, possibly, as suggested by Mr. Knobel, through errors in copying one letter for another closely resembling it.

The most important portion of the volume is the complete reduction of the observations made between 1625 and 1750.

These consist mainly of four eclipses and twenty occultations of stars observed by Bullialdus and Gassendi between 1620 and 1642; six eclipses and sixty occultations observed by Hevelius between 1639 and 1684; three eclipses and twenty-four occultations observed by Flamsteed between 1676 and 1716; six eclipses and ninety-seven occultations observed by La Hire, the Cassinis, Maraldi, and principally at the Paris Observatory between 1670 and 1740; and seventy-seven occultations observed by Delisle between 1714 and 1748, partly at the Luxembourg at Paris, and partly at St. Petersburg. Some of these observations have had to be rejected, principally from some uncertainty attaching to them, as, for instance, in the case of most of the occultations of stars by the bright limb of the Moon. Nearly two-thirds of them, however, are good observations, which can be used to determine the errors of the lunar tables for different periods between 1650 and 1725. They are sufficiently numerous to enable the mean errors of Hansen's tables to be determined with a probable error of only $1''{\cdot}5$ for any period between 1670 and 1740. Between 1625 and 1670 the probable error of the observed place is much greater, amounting to about $5''$.

In the last portion of the volume Professor Newcomb proceeds to discuss these observations and correct the elements of Hansen's tables. The results of his investigations have been already described in the last Report of the Council, and need not be again repeated.

There can be no doubt that these researches of Professor Newcomb, embodied in this volume of the *Washington Observations*, form a most important contribution to our knowledge of the motion of the Moon, and, by furnishing the mathematician with most valuable data, tend very materially to advance the theory of the motion of the Moon. It will make astronomers look forward with impatience to the publication of the second part of the research—the mathematical treatment of the theory of the terms of long period.

In relation to Professor Newcomb's volume Mr. Neison has remarked (*Monthly Notices*, vol. xxxi., p. 73) that if one of the eclipses be omitted, the value of the correction to the secular acceleration rises from $-3''{\cdot}81$ to $-4''{\cdot}80$; and that if two other eclipses which Professor Newcomb regards as doubtful be omitted, Hansen's value of the secular acceleration can be reduced to $7''{\cdot}20$, or only a single second greater than the theoretical value, $6''{\cdot}18$.

In a previous paper, "On Hansen's Terms of Long Period in the Lunar Theory" (*Monthly Notices*, vol. xxxviii., p. 268), Mr. Neison has given the results of a careful investigation in regard to the two terms of long period in the motion of the Moon due to the perturbations of *Venus*, which were discovered by Hansen. Purely empirical values were assigned by Hansen to the coefficients of these important terms. Delaunay found that the theoretical value of one of the coefficients was so small

that it might be regarded as insensible. This result was confirmed by Professor Newcomb, and Mr. Neison has sufficiently verified Delaunay's investigations to satisfy himself that they are free from serious error. Nevertheless, Mr. Neison arrives at the important and remarkable conclusion that it is possible that, after all, Hansen's result may be right, and he explains in the paper how this may be produced.

Mr. Hill's Researches on the Lunar Theory.

During the course of the past year mathematical astronomy has received an important contribution from the publication in the *American Journal of Mathematics* of Mr. G. W. Hill's "Researches on the Lunar Theory," a paper communicated to the American Academy of Sciences in April 1877. In these investigations Mr. G. W. Hill has regarded the problem from rather a different point to that usually adopted, and his aim is expressed in the opening paragraph of his paper in the following words:—

"When we consider how we may best contribute to the advancement of this much treated subject, we cannot fail to notice that the great majority of writers on it have had before them, as their ultimate aim, the construction of tables; that is, they have viewed the problem from the standpoint of practical astronomy rather than from that of mathematics. It is on this account that we find such a restricted choice of variables to express the position of the Moon, and of parameters, in terms of which to express the coefficients of the periodic terms. Again, their object compelling them to go over the entire field, they have neglected to notice many minor points of great interest to the mathematician, simply because the knowledge of them was unnecessary for the formation of tables. But the developments having now been carried extremely far without completely satisfying all desires, one is led to ask whether such modifications cannot be made in the processes of integration, and such coordinates and parameters adopted, that a much nearer approach may be had to the law of the series, and, at the same time, their convergence augmented."

Mr. Hill adopts rectangular coordinates instead of the usual polar coordinates, with the idea of simplifying the expression for the disturbing function and the perturbations. It is his opinion that the perturbations of the rectangular coordinates will be simpler in form than the perturbations of the ordinary system of polar coordinates; and in support of this view Mr. Hill adduces the case of elliptic motion, where the rectangular coordinates can be expressed by a series of circular functions of the time with coefficients of comparatively simple form

whose general term is known; whereas, in the case of the ordinary polar coordinates the coefficients of the series of circular functions are more complex and cannot be expressed by a general term of simple form.

Mr. Hill proceeds to convert the ordinary differential equations into the particular form made use of by him, the system of rectangular coordinates being supposed to rotate with the same velocity as the mean motion of the Earth, so that one of the axes always passes through the mean place of the Sun. He then proceeds to introduce as auxiliaries two new imaginary variables instead of two of the rectangular coordinates, and to transform the differential equations and disturbing function into terms of these new quantities. These new variables perhaps might be termed the imaginary square roots of the radius vector, and it is by the aid of these auxiliaries that Mr. Hill deduces the lunar perturbations. In the subsequent stages of his researches Mr. Hill supposes the eccentricities of the terrestrial orbit and the inclination of the lunar orbit, together with the solar parallax, to be so very small that they can be neglected. Under these conditions he is able to deduce two symmetrical differential equations of the second order in terms of the two imaginary auxiliary variables, and then, by suitably combining them, Mr. Hill derives two new differential equations which have the advantage of being symmetrical homogeneous equations of two dimensions, and well suited for the purpose of deducing the relations connecting together the different coefficients of the periodical perturbations.

Mr. Hill then proceeds to still further restrict the scope of his investigations by supposing the eccentricity of the orbit of the Moon to be so small that it can be neglected, and takes up the special consideration of the class of lunar perturbations which depend solely on the ratio between the mean motions of the Earth and Moon. He assumes that the variables are functions of these terms only; and he supposes that the values of the two rectangular coordinates of the Moon are expressed by a series of cosines and sines of the difference between the mean motions of the Earth and Moon, each periodical term being supposed to have an indeterminate coefficient. Mr. Hill then transforms his auxiliary imaginary variables into a series of powers of an imaginary exponential function of the time, with the same indeterminate coefficients as the series of cosines and sines expressing the value of the rectangular coordinates. It only remains, therefore, to deduce the value of these indeterminate coefficients by means of the equations involving the auxiliary variables, and, by substituting them in the series for the rectangular coordinates, their values will be obtained at once, without any further transformations or operations.

Substituting in the differential equations these expressions for the auxiliary variables, Mr. Hill is able to deduce equations connecting together the different indeterminate coefficients,

and so find an expression for the value of any single coefficient in terms of the other coefficients of the series. This constitutes Mr. Hill's solution of the problem. It gives the value of the perturbation in the form of a series of terms each of which has a coefficient consisting of a doubly infinite series which is a function of the other coefficients of the series. The method gives, however, only those terms which are independent of the eccentricity and inclination of the orbit of the Moon and the eccentricity of the orbit of the Earth and the solar parallax.

By means of these investigations Mr. Hill is able to deduce with accuracy the portion of the perturbations of the Moon which depend solely on the ratio of the mean motions of the Earth and Moon. They are calculated to the 14th decimal place by an arithmetical process, and to the order m^9 by algebraical development.

The concluding part of this portion of Mr. Hill's researches on the lunar theory is devoted to the special consideration of these results as applied to particular cases of the problem of a satellite moving in a circular mean orbit and disturbed by the action of a very distant body in the plane of the orbit.

The preceding account of these researches of Mr. Hill's will show that they form an important contribution to astronomy, and the highly original and powerful method by which Mr. Hill has attacked the problem will be generally admired. And if opinions may differ on some of the conclusions arrived at by Mr. Hill in the course of his researches, there cannot be any question as to the value of this important addition to our knowledge of the Lunar Theory.

Mr. Darwin's Investigation of the Influence of Geological Changes on the Earth's Axis of Rotation.

In a paper "On the influence of Geological Changes on the Earth's Axis of Rotation," * Mr. G. H. Darwin has considered the rotation of a spheroidal body which, from internal forces, is slowly and continuously changing its shape to a small extent. He arrives at the conclusion that, with changes such as those which geologists observe, the instantaneous axis of rotation would always remain sensibly coincident with the principal axis of figure, and that the change in the obliquity of the ecliptic could not exceed a small fraction of a second of arc. The principal axis of figure would, however, wander from its primitive geographical position in the Earth, and would carry along with it the instantaneous axis of rotation, the extremity of which would describe, at the Earth's surface, a cycloidal

* *Phil. Trans.*, vol. 167, part I., p. 271.

curve of very small linear dimensions, the two axes being coincident every 306th day. If the Earth be considered as plastic, it appears that its rotation would have the effect of modifying the path described in the body by the principal axis, under the influence of the internal forces. From this the author concludes that it is probable that, during the consolidation of the Earth's mass, the geographical position of the poles may have varied to a considerable extent.

The author then considers what amount of geographical change in the position of the poles in the Earth might arise from geological changes, and investigates the forms of elevation and depression which would produce a maximum effect. He concludes that, if the Earth were absolutely rigid, the pole could never have wandered more than from 1° to 3° from its primitive position; but that, if the Earth's mass be sufficiently plastic to admit of rough adjustments to an approximate form of equilibrium from time to time, then the wandering of the poles might be cumulative in successive geological periods. He regards it, however, as excessively improbable that the poles could thus have wandered more than 10° or 15° during geological history. The geographical changes in climate, observed in the geologically recent glacial epoch, seem too great to admit of explanation from this cause. The problem of the rotation of the Earth as modified by geological changes was considered from a more strictly astronomical point of view by M. Gyldèn in 1871; and Professors Haughton and Twisden have recently communicated papers to the Royal Geological Society on the same subject, which bear more on the geological aspects of the case.

Total Solar Eclipse of 1878, *July* 29.

Although no grant of money was made by the Government or from the funds of the learned societies for the observation of this eclipse, several English observers, at their own expense, transported themselves and their instruments, which in some instances were very bulky, to the Western States of America, for the purpose of placing themselves upon the line of totality. All the English observers were rewarded by fine weather.

The eclipse, which was visible along a track which passed across the States of Colorado and Texas, was also well observed by a large number of American astronomers, some of whom obtained excellent photographs of the corona, showing structure which differs materially from the structure visible in the photographs of the corona taken in 1871 near to a period of sun spot maximum. One of the English observers also obtained two photographs of the corona, which have since been presented to

the Society, and can be seen on applying to the Assistant-Secretary.

The stations of the English observers were as follows: Mr. Lockyer at Rawlins, Wyoming Territory; Mr. Loder, Mr. Penrose, and Mr. Ranyard, all within a few miles of Denver, Colorado; Dr. Schuster, Dr. Thorpe, and Mr. Hoskins at Las Animas, South Colorado.

Reduction of the Observations of the Transit of Venus of 1874.

The work in connection with the English Government Expedition has not proceeded as rapidly as in former years, Her Majesty's Treasury having, since the 31st of last March, refused to grant further pecuniary assistance. The work is too heavy to throw upon the Staff of the Royal Observatory, and must have collapsed had it not been continued at the expense of the Astronomer Royal and Captain Tupman. For the last eight months the latter has been working at the preparation of the calculations for the press without any assistance.

Considerable progress has, however, been made. When it was found that Mr. Burton's measures of the photographs presented such grave discordances, the Astronomer Royal requested Captain Tupman to remeasure the photographs; but no greater success was obtained.

A discussion of the Solar Parallax from every available observation of the recent transit was then undertaken, and the results, as well as those from the photographs, were presented to the Society in June.

Since then the details of the operations at the various Government stations, the bulk of which relate to the terrestrial longitudes, have been preparing for press. This is not very straightforward work, for small errors of calculation or transcribing are continually being detected and have to be corrected. It is in this that an assistant is most needed. The press copies may be said to be ready for the stations at Mokattam, Honolulu, Kailua, and Waimea. For Rodrigues the transits of stars are ready. It is not in contemplation to include the details of photography in the work.

It is believed that the whole will be printed in the form, and will constitute a portion, of the *Memoirs* of the Society.

Abroad, we have to notice that the French Commission has published the details of the Expedition to the Island of St. Paul under Captain (now Admiral) Monchez. About one-fourth of the work is devoted to the astronomical observations, the remainder to photography, pendulum experiments to determine the intensity of gravitation, magnetic observations, hydrography, and other valuable researches.

The Russian Commission has published the measures and the discussion, by Dr. Hasselberg, of 22 photographs taken at Hafen Possiet with an instrument, by Dallmeyer, similar to those used by the British parties. The position angles, as well as the distances of the centre of *Venus* from the centre of the Sun, have been most carefully determined. In the former a mean error of 10′ is found; for the latter a mean error of 1″—that is, of about one-twelfth part of the relative parallactic displacement of the centres. Compared together by reduction to one standard—that is, by eliminating the motion of the planet, the individual photographs vary as much as 4″ in the deduced distance of centres, much the same result as was obtained from the British photographs. In the Russian photographs the instrumental distortion was eliminated by employing a reticule of numerous lines, the positions of which, as depicted on the collodion, were determined by observation.

Elements of Vulcan.

The question of supposed transits of an intra-Mercurial planet has been again taken up by M. Oppolzer (*Astronomische Nachrichten*, No. 2239), who has collected the following eight observations, which may, he considers, refer to the transits of the same body:—

		d	Sun's Longitude. °		
1800	March	29·0	9	14	Fritsch
1802	Oct.	10·0	197	6	Fritsch
1819	Oct.	9·0	195	45	Stark
1839	Oct.	2·0	188	44	Decuppis
1849	March	12·18	352	2	Sidebotham
1857	Sept.	12·00	169	33	Ohrt
1859	March	26·22	5	23	Lescarbault
1862	March	19·87	359	20	Lummis

Five of these had been used by Le Verrier in his discussion published in the *Comptes Rendus*, tome lxxxiii., 1876, and to them M. Oppolzer has added the first observation by Fritsch and the two by Stark and Ohrt, which Le Verrier had rejected on the ground that no mention was made of any motion of the spot. The whole of the eight observations are well represented by the following elements:—

1850, Jan. 1·0, Paris M.T., Mean Equinox 1850·0.

M	356° 0′	i	7° 0′
π	27 45	μ	22°·789529
ϕ	14 13	log a	9·0906
Ω	178 0		

This planet is not identical with either of the objects seen by Watson in the late eclipse; it was at that time about 7° east of the Sun and in north latitude.

On further consideration, however, M. Oppolzer finds that there are various circumstances which tend to shake our confidence in these elements:—

(1) With such a small inclination and period of revolution, a transit should take place every year in March as well as in October, and it is difficult to account for the fact that more frequent observations of such phenomena have not been made.

(2) The representation of the earlier observations requires a large retrograde movement of the node.

(3) The duration of the transits corresponds well with the observations of Lescarbault, Loomis, and Decuppis, but is too small for Fritsch's observation in 1800, which requires a duration of 10 to 11 hours.

(4) For Sidebotham's observation in 1849 the time of conjunction falls in the early hours of the night.

Further, considering that by making the periodic time sufficiently small, a satisfactory solution may always be found, we may be inclined to think that the satisfactory representation of eight observations is merely an accidental coincidence. The question can be decided by observations on March 18 next, when, according to M. Oppolzer's elements, a transit will occur as follows:—

				Berlin M.T. h m	Pos. Angle. °
Ingress	1879	March	18	18 8	74
Egress				23 15	254

Discovery of Minor Planets.

The following minor planets have been discovered during the past year. The total number is now 191.

No.	Name of Planet.	Date of Discovery. 1878.	Place of Discovery.	Name of Discoverer.
(184)	Deiopeia	February 28	Pola	Palisa
(185)	Eunike	March 1	Clinton, U.S.	C. H. F. Peters
(186)	Celuta	April 6	Paris	Prosper Henry
(187)		April 11	Marseilles	Coggia
(188)	Menippe	June 18	Clinton, U.S.	C. H. F. Peters
(189)	Phthia	September 9	Clinton, U.S.	C. H. F. Peters
(190)	Ismene	September 22	Clinton, U.S.	C. H. F. Peters
(191)	Kolga	September 30	Clinton, U.S.	C. H. F. Peters

Planets (173), (177), (180), and (181), discovered in the preceding year, have respectively received the names of *Ino*, *Irma*, *Garumna*, and *Eucharis*.

Discovery of Comets.

Four comets have been observed since the date of the last Report, three of which are comets of short period.

1. A faint telescopic comet, discovered on July 7, 1878, by Mr. Lewis Swift, at Rochester, U.S. This comet was not observed in Europe, though carefully searched for; but Dr. Peters, of Clinton, U.S., succeeded in making four observations, from which Dr. Holetschek has calculated the elements of its orbit.

2. Tempel's second periodical comet, discovered in 1873, was first seen by M. Tempel on July 19, 1878, at the Arcetri Observatory, Florence. This comet has also been observed at several other Observatories.

3. Encke's periodical comet, whose return to perihelion was expected last year, was independently detected on August 3, 1878, by Mr. Tebbutt, at Windsor, New South Wales, and by Dr. Gould, at the National Argentine Observatory, Cordoba, by the aid of Von Asten's ephemeris in No. 2197 of the *Astronomische Nachrichten*. Dr. Gould has made a valuable series of observations, assisted by Mr. Thorne, extending from August 7 to September 6. He remarks that "the comet appeared nearly circular throughout the whole period of observation, and until August 26 a slight increase of brightness towards the centre was appreciable. Its light on August 10 was comparable with that of a star of the eighth magnitude; but, although the comet was moving southward and eastward, its light decreased so rapidly, that during the last ten days it was difficult to keep it in view while near the illuminated threads of the telescope. On August 17 the apparent diameter of the comet was very nearly one minute of arc."

4. Brorsen's periodical comet was found by M. Tempel, at Florence, on January 14, 1879, very near to the horizon. According to the elements calculated by Professor Schulze, the date of its return to perihelion is March 30; it has therefore been seen much earlier than was expected. In April and May this comet will be more favourably situated for observation in northern latitudes than at the last appearance in 1868.

Schmidt's Charte der Gebirge des Mondes.

This grand work, the labour of a lifetime, was published at Berlin in the early part of last summer. It forms a complete map of the lunar surface on a scale of 75 inches to the diameter

of the Moon, which is twice as great as the scale of either Lohrmann's larger map or of the well known *Mappa Selenographica* of Beer and Mädler. Schmidt's new map is divided into twenty-five sections on exactly the same plan as Lohrmann's Mondcharte, showing the same region, only on twice the scale—four times the area. The map is based exclusively on the trigonometrical survey of Lohrmann's, made in 1824 and published complete for the first time in 1878. This survey is far less extensive than that of Beer and Mädler, so that it forms a less accurate basis for a map, and on this account Schmidt's map shows systematic differences when compared with Beer and Mädler's *Mappa Selenographica*. The whole of the detail shown on Schmidt's map is derived from his own numerous drawings of the different lunar formations; so that, with the single exception of the relative position of the principal lunar central peaks, the new chart of Schmidt's is an absolutely independent delineation of the surface of the Moon. The published maps are exact reproductions by photolithography of the original pen and ink drawings of Herr Schmidt.

The portfolio of sections of this great map is accompanied by a short explanation of 20 pages, giving the names of the different formations, for the chart itself contains only letters and numbers. There is also published a quarto volume giving a fuller explanation of the chart, a comparison between the symbols of Lohrmann and Mädler, and a full account of the measures of the heights of the principal lunar peaks, made by Schroter, Mädler, and Schmidt. Although there are a few notes to each section, there is no detailed descriptive account of the principal formations on the lunar surface, though this feature is fully as important as the mapping of the surface, and forms an essential part of the great work of Beer and Mädler.

The history of this great chart of the Moon is well known to astronomers, who have for several years been anxiously awaiting its publication. Herr Julius Schmidt commenced accumulating material for his new chart whilst at Hamburg in 1843; and between 1843 and 1874 made more than three thousand drawings of different portions of the Moon. From these drawings the present map was constructed, a work fully occupying his time between April 1867 and July 1874. After some uncertainty as to the best method of publishing, Herr Schmidt accepted the offer of the German Government, and it is at their cost that the work has been at last published. It forms a most elaborate map of the detail of the lunar surface and is an important contribution to selenography.

Lohrmann's "Mondcharte."

After an interval of more than half a century, the remaining twenty-one sections of Lohrmann's large map of the Moon have at

length been published. Lohrmann was a land surveyor of Dresden, in the service of the Saxon Government, and an enthusiastic amateur astronomer. Encouraged by Gauss and Encke, he undertook the construction of a complete map of the Moon, employing a fine 5-inch Frauenhofer Equatoreal. The map was founded on a micrometrical triangulation of the principal points on the lunar surface, the measures being reduced by means of formulæ supplied to him by Encke. Lohrmann divided his map into twenty-five square sections on the scale of $37\frac{1}{2}$ inches to the diameter of the Moon, and he intended each section to be accompanied by a full description of the principal features of the portion of the lunar surface included within it. After four years' labour, the first four sections, with a descriptive letterpress, were published in 1824, and were warmly welcomed by astronomers as an important contribution to science. The second instalment of the work was anxiously expected, but it did not come. Up to 1827 Lohrmann had energetically continued his labours, but failing eyesight then compelled him to suspend his work. He never recovered sufficiently to enable him to resume his observations, and he died in 1840, leaving his work incomplete. It was generally supposed that, though he had issued, in 1837, a small lunar chart (15 inches in diameter), he had never completed the remaining sections of his large map. It now seems that this was not the case, and that, though Lohrmann had not obtained all the material that he desired, yet he had finished his sections on the basis of the observations made between 1821 and 1827. After many long delays, the remaining sections of Lohrmann's map have been engraved under the superintendence of Herr Julius Schmidt, the well known selenographer, and they were published at the beginning of last year. It would appear that Lohrmann left no written description to accompany his maps. The sections having been reproduced without alteration from Lohrmann's original pen and ink drawings, they represent a careful delineation of the lunar surface as it appeared half a century ago, and they form an important addition to this department of astronomy.

Publications of the Astronomical Observatory of Harvard College.

Since the last Annual Report of the Council, the Observatory of Harvard College has published some most important contributions to Sidereal Astronomy.

Vol. iv., part 2, of the *Annals*, published in 1878, contains the observations in Right Ascension of 505 stars determined with the East Transit Circle in the years 1862–65, under the direction of Professor G. P. Bond, and Professor T. H. Safford, who has now reduced the observations.

One chief difficulty in the instrument with which these

observations were made was the absence of collimators, and the collimation had to be determined by reversals on a distant mark. Professor Safford remarks, that "as the work progressed, and various discrepancies between the observations and some of the principal ephemerides became manifest, it was almost invariably found that the observations were the more accurate of the two."

The General Catalogue gives the mean Right Ascension to 0ˢ·001 of 506 stars for the epoch of 1865·0, with their precessions and secular variations computed from Bessel's elements, using Argelander's precepts and Tables in vol. vii. *Bonner Beobachtungen*. In the large majority of stars proper motions are given, derived from Argelander, Newcomb, Mädler, Von Asten, Wagner, Wolfers, Rogers, and Safford. Approximate declinations are appended. The Catalogue includes all the stars of the *Nautical Almanac* visible at the latitude of Cambridge, omitting Maskelyne's 36 stars; also 22 polar stars whose places were investigated in vol. iv., part 1, of these *Annals*,* and some other bright stars taken from the *Connaissance des Temps*, the *American Ephemeris*, and Argelander's *Gemeinschaftliche Sterne* and *Uranometria Nova*.

One especial value of this Catalogue is the large number of observations that has been obtained, the Right Ascensions of over 420 stars being deduced from at least 10 observations of each star. Professor Safford has appended to the Catalogue a very useful Table of the Annual Terms of the Standard Polar Stars.

* Professor Safford states that one object he had in view was the detection, if it existed, of a periodic error of rather complex form in Carrington's Right Ascensions, first suspected by Professor Benjamin Peirce, and published by him in *Gould's Astronomical Journal*, No. 114, vol. v., p. 137. As this journal is rather scarce, we give a brief quotation from Professor Pierce's paper. In comparing Carrington and Schwerd, he says: "Mr. Carrington's polar distances are upon an average 0″·75 less than those of Schwerd. This diminution of polar distance is not restricted to the stars in any especial locality, although it is rather larger for the stars which are more remote from the pole, and for those stars which are between 12ʰ and 18ʰ R.A. Mr. Carrington's Right Ascensions are also greater than those of Schwerd, and the difference is so great that when multiplied by the cosine of the declination it is on the average more than a second of arc."

Octant of α.	Mean Excess of Carrington's Polar Distance.				Mean Excess of Carrington's $\alpha \cos\delta$.			
	0° to 3°.	3° to 5°.	5° to 7°.	7° to 9°.	0° to 3°.	3° to 5°.	5° to 7°.	7° to 9°.
1	+0·31	−0·67	−0·45	−0·68	+1·20	+0·77	−0·09	+1·21
2	+1·30	−0·88	0·66	0·35	+0·50	1·46	+2·14	1·48
3	−0·06	+0·31	1·13	0·42	−0·01	0·03	0·99	0·78
4	0·54	−0·35	0·98	0·53	−0·12	1·00	1·09	1·66
5	0·06	1·52	1·30	2·04	+0·49	0·22	1·44	1·53
6	1·54	1·09	1·34	1·59	0·00	0·78	1·45	2·00
7	1·08	1·01	0·53	0·45	+1·07	0·84	0·94	1·23
8	−0·97	−0·51	−0·73	−0·37	+1·33	+1·67	+1·32	+0·74

Vol. ix. of the *Annals*, published in 1878, is devoted to the "Photometric Researches of Professor C. S. Peirce," a notice of which will be found elsewhere.

Vol. x., published in 1877, consists of "Observations made with the Meridian Circle during the years 1871 and 1872, under the direction of the late Professor Winlock, by Professor W. A. Rogers."

The Meridian Circle with which these observations were made has an object glass of 8·25 inches aperture, and 9 feet 4·4 inches focal length. The collimators have apertures of 8 inches and focal lengths equal to that of the chief telescope. The diameter of the circle is 3 feet and the length of the axis 4 feet. In the transit reticule a system of lines etched upon glass has been substituted for spider lines. The result of observations made for the purpose of ascertaining the amount of the loss of light from using glass was, that when microscopic cover-glass was employed it was imperceptible to the eye. All the wires (lines) used for transits are double, the star being observed when it is in the centre, between the lines. Professor Rogers remarks that the result of this is a slight diminution of the probable error of observation.

The observations, which are entirely differential, consist of the positions of 564 stars, of which 289 are found in the Catalogue of the *Astronomische Gesellschaft*. These primary stars furnish the positions upon which the remaining 275 secondary stars depend. We have, at pp. 201–211, Catalogue 1 of the 289 primary stars, giving their mean Right Ascensions and Declinations derived from the observations, with their annual variations for the epoch 1872·0, together with a column of corrections to the Catalogue of the *Astronomische Gesellschaft*. Catalogue 2, pp. 213–227, gives the mean Right Ascensions and Declinations for 1872·0 of the 275 secondary stars, derived from the observations, with their precessions and secular variations, and proper motions. The column of observations shows that a fair number in each element has been obtained. The original observations from which these Catalogues have been deduced are contained in pp. 1–199.

In discussing the proper motions, Professor Rogers commences by reducing to a homogeneous system in Right Ascension and Declination the various Catalogues compared; the standard system of Right Ascensions being that derived by Professor Newcomb, and published in *Washington Observations*, 1870, Appendix III., and for standard Declinations, those furnished by the *Astronomische Gesellschaft* for the reduction of the zone observations. Pp. xxxv.–xxxvii. give a most valuable series of equations for reducing each Catalogue of Right Ascensions to Professor Newcomb's system; being an extension of the corrections given by him at p. 43 of his Memoir, referred to above, which were limited to equatoreal and zodiacal stars. A complete discussion is also made of the corrections and residuals

in Declination to the various principal Catalogues. A novel and interesting treatment of this question is afforded by Professor E. C. Pickering, the present Director of the Harvard College Observatory, at pp. lvi.–lxvii., in a *Graphical Discussion of the Residuals in Declination*. A plate of graphic curves afforded by the Residuals in Declination of each Catalogue is given, in which the Declinations form the abscissæ and the deviations the ordinates. Taking the average of the residuals of all the Catalogues for the three periods, Bradley 1755 to Cambridge 1845, Greenwich 1845 to Harvard College 1872, and Bradley 1755 to Harvard College 1872, there is a very striking similarity in the form of the curves. From this discussion Professor Pickering derives Tables of corrections to the Right Ascensions on account of errors depending on the Right Ascension, and on the Declination, and a Table of the "Systematic Corrections to be applied to observed Declinations."

The above full discussion of this important subject will be highly appreciated by astronomers, and their labours in the determination of proper motions will be thereby much facilitated.

Appended to this volume is a Catalogue of the Mean Right Ascensions for 1868·0 of 604 Stars observed with the old Transit Circle, made and reduced by Mr. E. P. Austin, a large proportion of which appear to be dependent on single observations.

Mr. C. S. Peirce's Photometric Researches.

The Observatory of Harvard College has devoted the ninth volume of its *Annals* to the Photometric Researches of Mr. C. S. Peirce, which consist of a very valuable and elaborate investigation in this interesting but somewhat neglected branch of astronomy.

These researches were made by Mr. Peirce in the years 1872–1875, while engaged on the U. S. Coast Survey. At the instigation of the late Professor Winlock, a Zöllner's Astrophotometer was obtained for the Harvard College Observatory, and the author, who was temporarily appointed to duty there, was directed to prepare and carry out a plan of photometric observations. These appear to have been made at various stations of the U. S. Coast Survey, where the author happened to be located, and the resulting work, being submitted to Profesor Winlock, was accepted by him, and hence its appearance in the *Annals* of the Observatory of which he was the late Director.

An interesting chapter on the "Sensation of Light," and the different sensibility of the eye to lights of different refrangibilities, forms a fitting introduction to so elaborate a work on Photometry.

In chapter ii., "On the numbers of Stars of different degrees of brightness," the author explains his "method of equable distribution" which he has adopted as the basis of a system of star magnitudes. He says (p. 9), "If one observer says there are nine 1st magnitude stars in the northern heavens and another finds only eight, clearly the latter consigns some star to the 2nd magnitude which the other considers to be of the 1st, and therefore he makes the limit between the 1st and 2nd magnitudes to be brighter than the other makes it. Suppose that neither of two observers made any errors in his estimations, and that their discrepancies arose solely from the differences of their scales of magnitudes; then, if they observed the same stars, whichever had fewer stars brighter than the 4th magnitude, for example, would have made the limit between his 3rd and 4th magnitudes the brighter. In fact we might call these numbers a scale of magnitudes. If there were 175 stars brighter than the 4th magnitude, we might say that the limit between the two was, upon this new scale, the 175th magnitude." To determine his "scale of equable distribution" he further says, "I count all the stars which an observer finds of each magnitude in the northern heavens. Denote the sum of these, or the number as bright or brighter than each magnitude by $\nu(m)$. Then, for the scale of equable distribution, the numerical magnitude being m, we have

$$m = -\frac{1}{3} + 1{\cdot}892958 \log \nu(m).$$

In this way we shall obtain the magnitudes upon the scale of equable distribution of the limits of each class in the scales of the different observers."

Adopting this principle, Mr. Peirce proceeds to reduce the magnitudes in the following Catalogues: *Durchmusterung*, *Uranometria Nova*, Heis' *Atlas Cœlestis*, Ptolemy, Al Sûfi, Ulugh Beigh, Tycho Brahe, Hevelius, William Herschel, Zöllner, John Herschel, Seidel, and Behrmann; the discussion of each Catalogue being followed by a Table for the reduction of its magnitudes to the scale of equable distribution.

The *Durchmusterung* is considered by the author one of the best collections of star magnitudes we have, and he publishes a count of the stars of each tenth of a magnitude in this Catalogue. In discussing Heis's Catalogue, a long list of errata and corrigenda is given at p. 29, but the author has omitted to notice the extensive list of errata in this Catalogue by Tromholdt, published in vol. ix. of the *Vierteljahrsschrift*.

A very valuable analysis of the magnitudes in the principal MSS. and editions of the *Almagest* is given at pp. 36–46, the result of considerable labour. Pp. 57–83 contain all Sir William Herschel's star magnitudes arranged in groups.

This interesting and elaborate reduction of magnitudes to a uniform system occupies nearly half the volume; it is followed

by chapter iii., containing the original observations with a Zöllner's astrophotometer. The principle of this instrument is, that an artificial star is thrown into the field of a telescope, and its brightness is reduced by the rotation of a Nicol prism until it matches in brightness any real star which is in the field at the same time; the artificial star being produced by the flame of a kerosene lamp. A Table at p. 91, giving the magnitude of this artificial star for various dates throughout the period of observation, shows that the intensity of the lamp was liable to considerable fluctuations.

Various difficulties in observing are described and discussed, the author mentioning that the most difficult part of the observations with the instrument consists in putting the eye straight to the telescope. This is a difficulty which is peculiar to all photometric observations, and especially so in the method of limiting apertures.

Mr. Peirce's design was to obtain the magnitudes of all the stars in Argelander's *Uranometria Nova* between 40° and 50° of north declination, consisting of 368 stars; but about 100 additional stars were subsequently added to the programme. The stars were divided into 70 groups, "each consisting of neighbouring stars, these groups lying in two zones, and so that the boundary between two adjacent groups of either zone should have as near as possible the same right ascension as the middle of a group in the other zone. Each set of observations consisted in comparing the stars of two groups with the photometer star, thus comparing these groups with one another."

The observations having been completed, all the photometer readings were separately reduced to a scale of magnitudes, adopting a light ratio = 2·25. Lastly, the magnitudes of 340 stars were compared with the reduced magnitudes of the *Durchmusterung* to reduce them to that scale of equable distribution used in the comparative catalogue; for this scale the light ratio was found to be = 2·565. Pp. 128–138 contain a catalogue of 494 stars observed by the author, with the magnitudes computed by him compared with various authorities.

A cursory comparison of the author's results with the magnitudes of the *Durchmusterung* at once shows a marked discrepancy, which further examination suggests to be dependent upon the right ascension. In R.A. 0^h–12^h Mr. Peirce makes 66 per cent. of the stars brighter than they are given in the *Durchmusterung*, whereas in R.A. 12^h–24^h only 24 per cent. are brighter. Further on, at p. 171, where the author proceeds to discuss the probable error of his magnitudes, he finds the correction to them expressed by the following formula:—

$$-0^m{\cdot}04 + 0^m{\cdot}24 \sin (\alpha + 1^h\ 11^m).$$

It is stated in the concluding chapter, "On the form of the Galactic Cluster," that "the chief end of observations of the

magnitudes of stars is to determine the form of the cluster in which our Sun is situated." But this rather begs the whole question. If the stars were all of a uniform size, and their light, or magnitude, were proportional to the square of their distances, photometry would necessarily reveal the form of the solar cluster; but we have yet no direct evidence of this. It would seem that stellar photometry is much hampered by certain assumptions which are thought to be necessary and convenient; for instance, that the relative brightness of stars is dependent on their distance, that the faintest naked eye stars should be of the 6th magnitude, and that the light ratio for bright stars should be of a different value to that for telescopic stars. It is to be regretted that astronomers have not agreed upon a definite light ratio. Stampfer's determination of R, which was adopted by Argelander, = 2·56, for which Pogson substituted 2·512, because the logarithm = 0·4000. Seidel's results from stars down to 3½ mag. give R = 2·789; Steinheil, using the same instrument as Seidel, R = 2·819; Zöllner, with naked-eye stars, finds R = 2·427; Dr. Rosén's observations give R = 2·339, with an appearance of a larger value for the brighter stars; and Mr. Peirce gives log ρ = 0·486 − ·0162 m., which produces this series of light ratios for the several magnitudes:—

Mag.	
1	R = 2·950
2	= 2·842
3	= 2·738
4	= 2·638
5	= 2·541
6	= 2·448
10	= 2·109.

This is most unsatisfactory, and it does not seem that our knowledge of the photometry of the stars can be much advanced till an understanding is arrived at among astronomers on this important point. Exception may also reasonably be taken to Mr. Peirce's method of equable distribution; on the face of it, it is impossible it can be a true photometric scale, and it is really condemned by the author himself, who states (p. 170) that the discrepancies between Zöllner and himself must "ultimately be ascribed to the fact that the scale of equable distribution of chapter ii. is not an equiphotometric scale."

Still, the importance of Mr. Peirce's work should not be underrated; a more perfect scale may be used in reducing the original observations contained in this volume, and his labours may result in a series of magnitudes of far higher value than those given on his adopted theory.

Double Star Observations of the Lund Observatory.

A valuable contribution to double star astronomy was published in 1876 in vol. xii. of the *Lunds Universitats Årsskrift*, entitled, "Mesures Micrométriques d'Etoiles Doubles faites à l'Observatoire de Lund, suivies de notes sur leurs mouvements relatifs, par N. C. Dunér. Lund, 1876."

These observations were made in the years 1867 to 1875 with an equatoreal telescope by Merz of 9·6 inches aperture and 14 feet 1 inch focal length, or exactly the same size as the great Dorpat telescope. The measurements were made with a filar micrometer by Jünger, of Copenhagen, in which only one wire is movable. All position angles were measured by Professor Dunér, who followed the advice of Professor Otto Struve, by placing the double star between the wires separated from it by several seconds; and in measuring distances two measures were always taken, turning the micrometer screw first in one direction and then in the other.

The observations consist of measurements of distances and position angles, and estimates of the magnitudes of 442 double stars, mostly from W. Struve's Catalogue; approximate positions are given for the epoch 1870·0, with brief notes of the colours of the stars and a numerical indication of the state of the atmosphere.

The second part of the Memoir is devoted to notes on the relative motion of all the double stars of which measurements are given in the first part, and forms a pretty complete history of each double star. In discussing the measurements of double star observers, Professor Dunér gives the highest weight to those of W. Struve. The author has appended to his Memoir a Table, in which he has classified the double stars from the Dorpat Catalogue, measured by him, according to the extent of their relative motions: Class I. consisting of stars which have made a complete revolution since they were first measured; Class II. stars which have moved through 180° of their apparent orbit; and so on to Class IX., which consists of stars which appear to be only optically double.

One commendable feature in this important work on double stars is that it is not in Swedish; the author, to render his labours more widely available, has written it, in what is to him a foreign language; an example which we could wish were more commonly followed by some European academies whose languages are not generally known or studied.

Report on the Progress of Meteoric Astronomy during the year 1878 by Professor Alex. Herschel.

The past year has been one of great activity both in developing the theory and in extending the observations of meteors and meteor showers. To describe more than the principal of its meteoric occurrences would form too long a narrative to be suitable for this Report. The short review which follows of the past year's observations and researches relating to meteoric apparitions is therefore confined to recording some of the chief meteoric events which have taken place, and to reviewing very briefly some of the most important work which has been accomplished during the past year, in discussing observations, and in improving our knowledge of the theory and of the probable history and origin of meteoric bodies.

Aërolites.—A stonefall took place on October 13, 1877, near Alexinatz, a town on the Bugarska (or Morava) river, in the south-eastern part of Servia, specimens of which have been preserved and will be submitted to proper analysis and examination. A small stone is also related to have fallen on a house at Butzbach in Hesse, from a meteor which appeared on the night of August 21, 1878, and to have been presented to the Berlin museum; but of its aërolitic character no other information or authentic indication has yet been received.

Several mineralogical examinations of meteorites of great interest and completeness have been carried out, of which some of the most important examples and particulars may be thus related. In connection with that made of the Ställdalen meteorites (Sweden, June 28, 1876) by Professor Nordenskjöld, he has observed that some eight or nine meteorites, among many which appear to be entirely unconnected with each other in their dates of apparition, form with the Ställdalen ones a well-marked group, apparently individual and distinct, but which, Professor Nordenskjöld observes, will probably be found to be only one among many similar groups of aërolites which will hereafter be detected.* The distinguishing character of this group's chemical composition is the proportion by weight of silicon, and of the metals with which it is associated, in their elementary or unoxidised forms, the average percentage proportions of these elements in the *Hessleïtes*—as the group is designated, from the place of fall of one of its most important members—being with exceedingly small variations seldom amounting to 1 per cent., about

Silicon.	Magnesium.	Iron.	Nickel.	Calcium.	Aluminium.	Sodium.	Other Metals.	Total.
26·6	21·8	43·7	2·8	1·9	1·5	1·0	0·9	100·2

* *Transactions of the Geological Society of Stockholm*, 1878, No. 44.

The other metals, present in only minute quantities, so as to be not always detected in the several meteorites like the rest, are potassium, cobalt, manganese, chromium, and tin. The actual states of oxidation and combination in which this mixture of metals is found in the several aërolites of the group result, as Professor Nordenskjöld conjectures, from a series of oxidising and reducing influences to which they have been in turns subjected, among which a reducing action producing the metallic iron appears, from the microscopic injection of this metal (alloyed with nickel) into every part of the structure of the stones, to be the final or most recent stage of the processes which they have undergone. Monsieur Stanislas Meunier has shown * that the action of hydrogen on mixed chlorides of iron and nickel at a red heat is to form, by their reduction, a crystalline alloy of these metals intimately pervading and solidly cementing together stony fragments placed in them into a hard mass, the crystals of which resemble the crystalline varieties of the same alloy found in siderites, and which show to some extent, by section and etching the well known Widmanstättian figures which characterise meteoric iron.

That the operation of some similar conditions has produced in certain ancient lavas of our own globe considerable quantities of terrestrial "native" or metallic iron is now a thoroughly well determined fact, from the concurrent testimony of many observations and researches. The detection of the native metal by Professor Andrews in the Irish basalts, corroborated in those of Bohemia by Professor Reuss,† assumed quite recently a fresh significance from the recognition also, by Monsieur Daubrée, of native or metallic nickel-iron as an alloy with platinum in certain rocks ("Dhunite") resembling serpentine, or magnesian silicates.‡ But its detection in visible grains in the basalt or lava rocks of Assuk, Disko Island, a part of the same basaltic range, although 100 miles from the spot, of Ovifak, in Greenland, where Nordenskjöld's discovery of the vast masses of metallic iron was made, together with other evidence collected in two visits to the same district by Professor Steenstrup, of Copenhagen,§ have latterly most strongly supported this conclusion that metallic nickel-iron is an abundant native product in some terrestrial lavas.

Pursuing this investigation to its close by analysing and

* *Comptes Rendus*, vol. lxxxvii., p. 855, December 2, 1878.

† "Address to the British Association, Dublin, 1876," by Dr. Andrews, vol. of the *British Association Reports for* 1876, p. lxxiii.

‡ *See* the last of these *Reports*, these *Notices*, vol. xxxviii., p. 220, last note of the page.

§ *Om de kulförende Dannelser paa Öen Disko &c.*, Copenhagen, 1874; and *Om de Nordenskiöldske Jærnmasser &c.*, Copenhagen, 1876, by K. J. V. Steenstrup, with a map and coloured plates. A translation into English of M. Steenstrup's Memoir has been published by M. Roche, one of his companions in his expeditions, who has now returned to Greenland for further explorations.

comparing together the materials collected on the spot and sent to him for this purpose by the different explorers of this district, Dr. Lawrence Smith has now amply shown, by a variety of proofs and comparative analyses,* not only that the celebrated masses of nickel iron of Ovifak are without doubt of terrestrial origin, but also that many smaller iron blocks discovered on the east and west coasts of Greenland by successive navigators (those recorded by Captain Sir J. C. Ross among the number) resemble each other and the Ovifak iron remarkably, while they differ essentially from meteoric iron by the large proportion of combined carbon in their composition. These scattered iron masses have been found at places on the east and west coasts of Greenland which are entirely confined to a region between the parallels of N. latitude 69° and 76°, where the coast is basaltic, and, like the larger masses found in the same region by Professor Nordenskjöld, Dr. Lawrence Smith now shows conclusively that they are all geological productions of the immense lava field which covers to an enormous (and northwards to an unknown) extent the greater part of northern Greenland.

The process of reduction to which the metallic masses owe their origin is ascribed in the Memoir to the beds of lignite and to vegetable remains in the strata which the immense tracts of lava overlie. From this view, which is not a less probable one than the supposition which he himself had formerly advanced—that metallic iron reaches the Earth's surface associated with basic igneous rocks, from depths in which it is naturally metallic and unscorified—Monsieur Daubrée, in his review of the Memoir, finds no reason to dissent; his own experiments having, in fact, already proved † that such terrestrial rocks (selected as presenting the greatest similarity to stony meteorites) are reduced by fusion, in charcoal-lined crucibles, with formation of metallic nickel-iron; and indeed that they crystallise on cooling into aggregates of their component minerals, hardly distinguishable from separate crystallisations of the same minerals which occur in meteorites. But the large quantity of graphite and of combined carbon found in the Greenland iron masses distinguishes them from meteorites, and probably shows that it is mainly to the action of carbonaceous gases and substances upon their fused materials that the natural smelting process which these lavas have undergone must be ascribed.

Comets.—Leaving to mineralogists and comparative geolo-

* In a paper accepted for insertion in the *Mémoires des Savants Etrangers*; *see* Dr. L. Smith's abstract of the Memoir in *Comptes Rendus*, vol. lxxxvii., p. 674, and M. Daubrée's report and observations on the paper, *Ibid.*, p. 911.

† *Comptes Rendus*, vol. lxii., pp. 200, 269, 660, Jan. 29—March 19, 1866; and *Bulletin de la Société Géologique de France*, vol. xxiii., p. 291, 1866. A detailed account of M. Daubrée's experiments on the artificial production of meteorites, as described in these papers, will be found in the *British Association Reports*, vol. for 1868, p. 415.

gists*—as Professor Newton does in an important mathematically and philosophically conducted Essay which he has lately published † on the almost inscrutable question of the distant birthplace and primitive fields of revolution of periodical and non-periodic comets—the much more mysterious question of how these bodies were consolidated in those regions into the nuclear orbs or parcels of fragments from which it seems not improbable that the coherent masses of aërolites and shooting stars are detached, we may welcome the new researches of the renowned explorer of the November meteor-stream as a much needed contribution towards a final solution of the immensely large and apparently space-pervading problem of celestial mechanics which he has attempted to resolve.

Two, if not three classes of comets, it seems probable from the discussion, although not presumed to be certainly distinct, may present themselves for observation: those of very short and those of much longer (it may sometimes be only suspected) periods of revolution, both of which classes may possibly (but not necessarily) have had their origin, like the asteroids, in the contraction of the solar nebula. Regarding a third and much larger class however, from a discussion of the inclinations of their orbits, Professor Newton is led to the conclusion by various considerations, among which the prevalence of large inclinations of the orbits may principally be noticed, that such an explanation of the origin of the major and principal part of the observed cometic orbits is far from being easily reconcilable with the existing data; and that the cometic hypothesis of Laplace, which regards them as bodies foreign to, and, in their motions and primitive history, independent of the solar nebula, is, on the contrary, well borne out by the collective examination. A rather larger number of the steepest comet-orbits are found with inclinations a little exceeding, than with those a little less than 90°; but the visibility of comets, regarded as accidental visitors in the solar system, is almost entirely dependent, as Laplace has shown, upon their pursuing towards it nearly parabolic orbits; and agreeably to this consequence of the theory of probability, certainly recorded cases of comets with decidedly hyperbolic orbits are extremely rare. In the course of an unknown and prodigious lapse of ages, as suggested by Professor Newton, a certain number of comets with apparently parabolic paths may have accumulated upon our list, and may have been deflected from more rapid courses into some which are either nearly or may be actually (although not perceptibly so to our observation)

* *Cours de Géologie comparée*, Paris, 1874, is the title of an introductory lecture-course on geology at the Muséum d'Histoire Naturelle, in Paris, by M. St. Meunier, in which all the results of his own and M. Daubrée's researches on meteorites are related in a clear, copious, and collective form.

† "On the Origin of Comets," by H. A. Newton, *American Journal of Science*, vol. xvi., p. 166, September 1878.

closed curves. The effect of the planetary perturbations by which the speed of some external comets has thus probably been arrested is in general to increase the inclinations, especially of steeply described orbits, and thus a slight anomaly which the curve of frequency of the orbit inclinations exhibits in that part of its range is satisfactorily explained.

The evidence so strongly and distinctly shown in favour of the theory of the original motion of most, if not of all, of our recorded comets in spaces far external to the solar nebula rests upon the assumption that the comet-yielding matter of the primitive nebula, if it existed, was confined, like that which formed the planets, to the neighbourhood of the ecliptic plane. This ground of the conclusion may admit of an exception that a similar distribution of the inclinations of the orbits to that which Laplace's hypothesis requires would have been produced were this matter otherwise spread uniformly on a very distant sphere, instead of in the distant portions of a disk or annulus. But the plan of the planetary motions in the solar system, and the analogy which they present to spiral and disk-like nebulæ in the heavens, scarcely allows us to assume with reasonable probability such a different disposition of the matter of the outer part of the nebula from what the courses of the planets show us must have been its original mode of distribution and of gradual contraction near the centre; and with no evidence before us of the past or present existence of a distant spherical envelope of nebular matter enclosing the solar system, we may certainly prefer to accept, with Professor Newton, the much simpler conclusion to which he is finally conducted by his well executed labours, that, with the exception of a few, perhaps, of the zodiacal comets, and comets of the shortest periods, all the comets which have been recorded are originally denizens of the interstellar spaces, pursuing unknown orbits like the stars, and separated, at least, and dissevered in their primitive astronomical relations from any connection with the nebular matter which, in the process of concentration supposed by the nebular hypothesis, formed the Sun, the planets, and the asteroids.

Meteors and Meteor Showers.—It was by a close and critical examination of the observed course and extent of the change known as the diurnal variation of the rate of frequency of ordinary shooting stars that an approximately correct knowledge of the real forms of the orbits of shooting stars was first obtained, and that the large excentricities or elongations of these orbits, and their resemblance to the orbits of comets was first shown by Newton and Schiaparelli. But a closer inspection of the known curve of diurnal variation as recorded by Coulvier Gravier, and by Schmidt and Zezioli, with all the new developments which the established theory of meteor showers has since then received, now leads Professor von Niessl, of Brünn, by an exact comparison of the theory with the observations, to a rather

different result.* It is not, in fact, single bodies reaching his standpoint from all surrounding directions, but flights of meteor particles parallel to such lines, or to such axes of radiation of their diverging streams, which invade the whole visible extent of an observer's horizon, and require him to register their numbers. Supposing the original directions of these axes to be evenly distributed, and the streams themselves to be originally of equal closeness or richness along their several axes, the effect of the Earth's speed of motion through them will not only be to cluster the radiant points together, but also to increase the apparent richness of the individual streams round the apex of the Earth's way. In the same way, neighbourhood of a radiant point to an observer's zenith renders the apparent abundance of its stream much richer than when the radiant point is near the horizon. Giving these and similar allowances due consideration, it appears that, on the average of the whole year, a morning maximum of meteoric frequency about three times greater than the mean midnight frequency (instead of scarcely $1\frac{1}{2}$ times as great, as observed) should be expected, and the hour of maximum abundance should be at 6 o'clock; while, by common consent of the three recorded curves of frequency, it takes place at about 3^h A.M. It is not possible to remove this last discrepancy, as Professor von Niessl shows, by substituting for the parabolic velocity of the modern meteor theory any different average velocity of shooting stars; nor is it a possible effect of daybreak (known or unknown to the observers), which is excluded by the proper treatment of the observations. But it may be suggested that a simpler, and perhaps sufficient, explanation of the difficulty will be furnished by a certain superabundance of radiant points above what an originally even distribution of them would require, which is found in the catalogues (according to a Table of some of them arranged to show this by von Niessl) near the antiapex of the Earth's way. The setting and cessation of these radiant points soon after midnight may perhaps cause the growing rate of frequency of shooting stars up to the first two or three, to abate again considerably in the later morning hours. The motions of periodic comets, especially of those with short periods, are in general direct, and the inclinations of their orbits to the ecliptic are for the most part inconsiderable; in their frequent approaches to the Sun, the disintegration of these comets into closed and continuous meteor streams also proceeds more rapidly than in comets moving in less restricted or much longer-cycled orbits. That a preponderance or undue abundance of meteors and meteor showers overtaking the Earth and falling upon it from the region round the antiapex should be discovered both in the fullest catalogues of meteor showers, and, as it seems possible to recognise also, in the marked peculiarity of the time of the

* "Ueber die tägliche Variation der Sternschnuppen," von Prof. G. v Niessl, in Brünn; *Astronomische Nachrichten*, No. 2222, vol. xciii. p. 209, Oct. 14, 1878.

morning maximum frequency of shooting stars, appears accordingly to be in very good agreement with what the existing astronomical theory of their origin would lead us to expect.

In the course of calculations of the real paths of many recent fireballs, such close and frequent repetitions in the positions of some of their radiant points have been noticed by Professor von Niessl as to induce him to give this observation some attention. Many very striking and remarkable cases, even exhibiting a certain regularity in the time of inactivity intervening between two successive resuscitations of a radiant point, have been similarly noticed among ordinary meteor showers by Mr. Denning.* With regard to these occurrences of concentric meteor flights, von Niessl remarks that, in any theory of physical connection which may possibly be projected to account for them, the condition of their pursuing orbits, which, in extent and excentricity, present even distant resemblances to parabolas,† must be rejected, and regarded as an inadmissible hypothesis. A single example from among the long list of instances produced by Mr. Denning will show the complete baselessness of any project for connecting together physically, with orbits at all resembling those of comets, two pretty nearly identical meteor showers as they are instanced by Mr. Denning, and as they are currently regarded in many radiant lists.

☄ 1680 ♉, Dec. 26, 132+21·5.	☄ 1833 ♉, Jan. 27, 135+25.
Dec. 21—Jan. 5, 130+20; Denning, 1876-77 (a feeble shower).	1877, Jan. 19, 135+27 (± 5°) (Large fireball seen in Ireland and the West of England.) Feb. 13, 133+26; S.Z. 32.

Of the two meteor observations here described, giving nearly recurring radiant points in *Cancer* near the beginning and end of January 1877, the first is an expiring shower of the "October—December Cancrids," diverging from that place, and the second is nearly identifiable with the first approach of the second display of the "February—April Cancrids" at the same place as the centre of the former group. Two comets with parabolic orbits are also so nearly concentric with these two meteoric systems as to be practically identifiable with them; but, owing to the difference of about thirty days between the dates of their two nearly concentric radiant points, no two parabolic orbits more widely dissimilar or more entirely disconnected from each other could very well be selected. Each of them nearly crossing the Earth's orbit, the comet of 1680 almost grazed the Sun's surface in a plane steeply inclined to the ecliptic before returning to the depths of space nearly upon its former track; the comet of 1833, moving almost in the ecliptic plane, overtook the Earth, crossed its orbit in a wide sweep to the other extremity of a

* These *Notices*, vol. xxxviii. p. 111, Jan. 1878.

† Or, it might be added, "to conic sections round the Sun." [G. L. Tupman.]

diameter drawn through the Sun, where it again encountered the Earth's orbit even more closely than before, having never approached much nearer than to mid-distance of the Earth's orbit from the Sun. But this is not an exceptional example; it is, on the contrary, a common instance of the alteration in a parabolic orbit which even a few days' interval suffices to produce in concentric comet radiant points and meteor showers. To discover a physical connection between the comets of 1680 and 1833 would be nearly as impossible as to track them both through their entire revolutions; and if concentricity of successive showers is a proof of their physical connection, it must be owing to a very different class of orbits from those of comets being the real paths of revolution of a rather large proportion of the streams or systems of ordinary shower meteors which have been observed.

Among the many dissimilar kinds of bodies which it is thus not at all improbable may be circulating in the solar system, one of the meteors described in the accompanying list of fireballs whose real paths have been determined, observed by Captain Tupman on the night of the 27th of November 1877, must here be prominently noticed as occupying a very singular position.* The simultaneous observations of its apparent course at Greenwich and at Writtle (fully confirmed by one obtained at Bristol) perfectly define the real height, locality, and direction of the meteor's motion, and its length of path. At the same time, its aspect to the observers was one of the most remarkable, by its slowness and duration, which fireballs sometimes, but not very commonly, present. Its stately course of 30° or 40°, in which it was, towards the end, about as bright as *Venus*, occupied not less than seven or eight seconds at Writtle (where a part of it near the close seems to have escaped observation), and fully 15 or 20 seconds at the Royal Observatory, Greenwich, where, as it faded out at last, Captain Tupman observed it moving there with extreme slowness. It began as a small shooting star, and was only white and brilliant in about the last quarter of its track, with a red spark-train, but leaving no permanent light streak visible upon its course. From its real altitude of 56 miles above the east point of Kent to 14 miles above a point near St. Omer, on the French coast, the relative velocity of its motion cannot have appreciably exceeded 5 or 6 miles per second. But the direction of its relative motion being at the same time just perpendicular both to the Earth's path and to the plane of the ecliptic, its velocity in that direction could not have been less than about 19 miles per second if its real orbit had been parabolic. The real velocity of the meteor in its orbit was accordingly only 19½ instead of 26, or *not so much as one mile*, instead of nearly eight miles, per second greater than the Earth's, as it should have been had the meteor's orbit been a very long elliptic or a parabolic

* "On a Meteor of Short Periodic Time," by Captain G. L. Tupman, *British Association Reports*, vol. for 1878, "Report on Luminous Meteors," Appendix II., Large Meteors.

one. It must, on the contrary, have been very nearly circular, and by calculation the following elements of it have been obtained by Captain Tupman, showing that the major axis, excentricity, and plane of the real orbit are not extremely different from those of the orbit in which the Earth revolves round the Sun.

$q = 0{\cdot}9858$	$\pi = 70^\circ\ 6'$	Motion direct.
$\epsilon = 0{\cdot}1568$	$\Omega = 245\ 50$	Periodic time 462 days
$\phi = -4^\circ\ 16'$	$i = 15\ 0$	

It will be interesting to notice if other orbits of fireballs similar to this one will hereafter be observed, which appears to indicate that a ring of minute bodies, not unlike the system of the asteroids, may be accompanying the Earth upon its track.

The other fireballs of the accompanying list were for the most part widely observed, and their real paths have been pretty reliably determined. Those of the detonating meteors of December 24, 1873, and August 11, 1878, by Messrs. Cleveland Abbe,* and Daniel Kirkwood † in America; those of the meteors of December 9, 1877, and April 2 and November 18, 1878, by Captain Tupman, and Professor Herschel; and those of large fireballs on March 25, May 12, June 7, and July 29, 1877, by descriptions of their appearance in England, which are there compared together, in the Report for 1878 of the Luminous Meteor Committee of the British Association. The roughly observed relative velocities of these meteors are compared in the Table with the theoretical or parabolic ones, and in its last column the Table also shows the nearest known meteor showers or comet orbits with which the rare spectacles which these large meteors presented appear to have exhibited, in the positions of their radiant points, some traces of resemblance.

* Report of the Committee to collect information relative to the Meteor of December 24, 1873. (Committee: Peter Parker, Cleveland Abbe, W. L. Nicholson). *Proceedings of the Philosophical Society of Washington*, vol. ii., p. 139, April 7, 1877.

† *The Analyst*, Journal of Mathematics, vol. v., p. 178, Les Moines, Iowa, U.S., 1878.

Real Paths of Large Fireballs obtained from Duplicate Observations, principally in the Year 1878.

G.M.T. (or Local Time); Size, and other features of the Fireball's appearance.	Places of Observation.	Meteor's Real Course. Distances in British Statute Miles. Height and Locality of the Points of First Appearance.	Height and Locality of the Points of Disappearance.	Real length of Path and Speed of Motion.	Observed Radiant Point.	Nearest known Radiant Point, and Remarks.
1873, Dec. 24 (7^h 39^m p.m. W.M.T.) Conical nucleus, brighter than full Moon; yellow, with short tail of red and blue sparks. Burst (?) with loud detonation; left no streak.	Washington, and neighbouring towns in Virginia and Maryland; and at Richmond, Newark, Danbury, &c., in the United States.	About 90 miles over a point near Newcastle, in the northern part of Delaware State, 30 miles S.W. from Philadelphia.	10, or 20 (?), miles over a point near Fairfax Cty., Virg., 30 or 60 (?) miles W.S.W. from Washington. Distance of the track from Washington, by the sound interval there, 31 miles.	Not definitely assignable, from the vagueness and conflicting nature of the data; probably about 120 miles in 3 to 5 seconds. (The parabolic speed is 35, and the observed speed probably about 30 miles per second.)	60° S. from N., alt. 25° by the mapped track. (Or at 115+38, near π, *a Geminorum*; but a possible range of the meteor's direction from about 113 (±3°)+32 (±6°) is admissible from the observations.)	[105+32, Nov. 23–Dec. 27, Geminids (Greg, 178); 108+36, Dec. 31, 1872, Denning (1876, *a*), 27; a radiant near *Castor*]. Account of the meteor (by a Committee of the Society), in the *Proceedings of the Philosophical Society of Washington*, vol. ii., pp. 139–161, with a map of the meteor's real course; April 7, 1877.
1877, Nov. 27, 10^h 26^m p.m. ¼ Moon's diam., in mid-course; blue, globular, with sparks; curved and extraordinarily slow motion, about 22 secs.	Greenwich, Writtle, and Bristol. (The appearance and real path of the meteor were observed and calculated by Captain Tupman).	56 miles; 11 miles north of Margate, Kent.	13 miles; 12 miles W. of St. Omer, France.	78 (±5) miles in not less than 15 seconds. Velocity not greater than 5 miles per second. (Parabolic speed 19 miles per second.)	285 (±1°)+64 (±5°); at ¼ (δ, o) *Draconis*. Connection of the meteor with the stream of Draconids (Greg, 166, D.G. 3, Heis, D, and Schmidt) in Nov.–Dec. seems doubtful.	The real orbit must be nearly circular. Period about 500 days, motion direct, descending, inclination about 15°.
1877, Dec. 9, 8^h 12^m p.m. A fine meteor = 1*f*, with long course and streak; "mauve"-purple and green colours.	Royal Observatory, Greenwich, London, Bromley, and Writtle (Chelmsford). Three or four good observations compared together by Captain Tupman.	55 miles over Stoke Ferry, Norfolk.	36 miles over Stratford-on-Avon.	100 miles in three seconds by two estimates of the duration. Velocity 33 miles per second. (Parabolic speed 35 miles per second.)	112+27; between β and ι *Geminorum*. All the observed paths conform to it very nearly.	108+28, Dec. 9, 1877, Corder. A sharply defined radiant of streak-leaving meteors (of which this was one) apparently not Geminids, with long courses, not visible with the Geminids at 107+35 on the 10th.
1878, March 25, 10^h 22^m a.m. Large meteor in sunlight; conical, white, with red tail; burst, and left a smoke-wreath visible for 10^m or 15^m.	Dunbar, Dundee, &c., East coast of Scotland; and North of England.	50 miles; 30 miles E.S.E. from Berwick.	22 miles; 45 miles E.N.E. from Aberdeen.	130 miles in about 4 seconds (or 33 miles per second); not very certain estimations. (Agrees with the parabolic velocity.)	332–20 (±5°); near ν *Aquarii*; 8° south of the ecliptic, and preceding the Sun's place 32° in R.A.	Very bright, near Dundee, even when passing close to the Sun. The perihelion distance of the real orbit is very small, = 0·02.

1878, April 2, $7^h\ 54^m$ p.m. Detonating fireball; $\frac{1}{3}$ Moon's diam.; red; slow, halting motion; burst into fragments.	Blackheath, Birmingham, and Leicester. Calculated path by Captain Tupman and Professor Herschel.	60 miles; 10 miles S. from Leicester.	15 miles (end-height very well determined); 5 miles W. from Coventry, 35 miles (agreeing with the time interval of the sound) from Leicester.	50 miles (beginning and length of path not very certain) in 3 or 4 seconds. (Agrees with the parabolic speed of 13 miles per second.)	177+49 (±3°); near χ *Ursæ Majoris*.	180+49, April 1–15, Heis, M. 7. A principal radiant of the April Ursids, whose streams are all nearly anti-apical.
1878, May 12, $8^h\ 53^m$ p.m. $\frac{1}{4}$ Moon's diam.; white, leaving sparks and a fragment near its disappearance. A detonation heard at Galashiels.	Edinburgh and the neighbourhood, in Scotland; York, and the North of England.	78 miles over Northallerton, Yorkshire.	17 miles over Boness, near Edinburgh; passing at a height and distance of about 34 miles nearly over Galashiels.	155 miles in about 10 seconds, reckoned, from several good estimates, for the whole flight. The parabolic velocity is 15 miles per second.	214−7 (±4°); near ϵ *Virginis*.	210−10, May, Denning 47 (1877), a rich, new shower. [Forshey, April 18, 1841, 198–8; exact radiant of a bright meteor shower. (*Am. Jour. of Sci.* vol. xlii. p. 395.)]
1878, June 7, $9^h\ 53^m$ p.m. $\frac{1}{4}$ Moon's diam.; blue, with reddish, flickering tail, and long, slow flight; left no streak.	South-western part of England; London, Kent, Shrewsbury, &c.	65 miles; 20 miles W.N.W. from Guernsey, Channel Islands.	37 miles; 15 miles E.N.E. from Lundy Isle, Bristol Channel.	160 miles in 8 or 9 seconds (by one good and several other estimates). Velocity about 19 miles, parabolic speed 20 miles per second.	247−25 (±5°); close to *Antares*.	248−20, fireball of June 17, 1873, Galle and von Niessl.
1878, July 29, $9^h\ 25^m$ or 30^m p.m. $\frac{1}{3}$ Moon's diam.; vivid white flash, and long spark-track; bursting at last; motion swift.	Manchester, Lancaster, and N. Wales and Cumberland.	82 miles; 8 miles W. from Manchester.	20 miles; midway between Preston and Blackpool, coast of Lancashire.	70 miles in about 3 seconds, by two estimates reckoned for the whole course. Velocity about 23 miles, parabolic speed 21 miles per second.	290 + 42 (or between 285+45 and 300+35, from the best recorded tracks); near δ *Cygni*.	284+44, end of July, 1878, Denning. A radiant point of some bright meteors.
1878, Aug. 11, about $10^h\ 10^m$ p.m. $\frac{1}{3}$ diam. of and outshone full Moon; greenish; burst into three red fragments, and detonated.	Bloomington, Indiana; Virginia and Pennsylvania. Notice and calculation of the meteor's path by Professor Kirkwood.	About 77 miles over the northern part of Western Virginia (350 miles due E. from Bloomington, alt. 10°).	15 or 20 miles (?) over Crawford County, Pennsylvania. Distance (by interval of the sound) west of Titusville, in that county, 25 miles.	About 170 or 180 miles in two seconds (an "uncertain" estimation); motion swift, and apparently hyperbolic (?).	Nearly horizontal and due south. But an exact position of the radiant point cannot be indicated.	*The Analyst*, U.S. Journal of Mathematics, vol. v. p. 178, Iowa, 1878.—The observations are few and incomplete, but difficult to reconcile with a parabolic speed of 20 miles (*circa*) per second.
1878, Nov. 18, $9^h\ 50^m$ p.m. A fine, slow-moving meteor, as bright as *Jupiter* or *Venus*.	Bristol and Writtle (Chelmsford). Real path calculated by Captain Tupman and Professor Herschel.	70 or 80 miles; midway between Nantes and Angers, France.	45 or 50 miles; midway between Le Mans and Laval, France.	About 70 miles. The duration of the meteor's flight was not recorded.	354+1, at λ *Piscium*. [The radiant point of δ 1743 I. (Clausen's) is in this constellation from the middle of the month of November to that of February.]	350+2, Dec. 1–2, 1877, Denning. A radiant of several slow meteors, one of them a fireball. 4+4, December, Schmidt.

Real Paths of Large Fireballs obtained from Duplicate Observations, principally in the Year 1878.

G.M.T. (or Local Time); Size, and other features of the Fireball's appearance.	Places of Observation.	Meteor's Real Course. Distances in British Statute Miles. Height and Locality of the Points of First Appearance.	Height and Locality of the Points of Disappearance.	Real length of Path and Speed of Motion.	Observed Radiant Point.	Nearest known Radiant Point, and Remarks.
1873, Dec. 24 (7^h 39^m p.m. W.M.T.) Conical nucleus, brighter than full Moon; yellow, with short tail of red and blue sparks. Burst (?) with loud detonation; left no streak.	Washington, and neighbouring towns in Virginia and Maryland; and at Richmond, Newark, Danbury, &c., in the United States.	About 90 miles over a point near Newcastle, in the northern part of Delaware State, 30 miles S.W. from Philadelphia.	10, or 20 (?), miles over a point near Fairfax Cty., Virg., 30 or 60 (?) miles W.S.W. from Washington. Distance of the track from Washington, by the sound interval there, 31 miles.	Not definitely assignable, from the vagueness and conflicting nature of the data; probably about 120 miles in 3 to 5 seconds. (The parabolic speed is 35, and the observed speed probably about 30 miles per second.)	60° S. from N., alt. 25° by the mapped track. (Or at 115+38, near π, *a Geminorum*; but a possible range of the meteor's direction from about 113 (±3°)+32 (±6°) is admissible from the observations.)	[105+32, Nov. 23–Dec. 27, Geminids (Greg, 178); 108+36, Dec. 31, 1872, Denning (1876, *a*), 27; a radiant near *Castor*]. Account of the meteor (by a Committee of the Society), in the *Proceedings of the Philosophical Society of Washington*, vol. ii., pp. 139–161, with a map of the meteor's real course; April 7, 1877.
1877, Nov. 27, 10^h 26^m p.m. ¼ Moon's diam., in mid-course; blue, globular, with sparks; curved and extraordinarily slow motion, about 22 secs.	Greenwich, Writtle, and Bristol. (The appearance and real path of the meteor were observed and calculated by Captain Tupman).	56 miles; 11 miles north of Margate, Kent.	13 miles; 12 miles W. of St. Omer, France.	78 (±5) miles in not less than 15 seconds. Velocity not greater than 5 miles per second. (Parabolic speed 19 miles per second.)	285 (±1°)+64 (±5°); at ¼ (δ, ε) *Draconis*. Connection of the meteor with the stream of Draconids (Greg, 166, D.G. 3, Heis, D, and Schmidt) in Nov.–Dec. seems doubtful.	The real orbit must be nearly circular. Period about 500 days, motion direct, descending, inclination about 15°.
1877, Dec. 9, 8^h 12^m p.m. A fine meteor = 2ℓ, with long course and streak; "mauve"-purple and green colours.	Royal Observatory, Greenwich, London, Bromley, and Writtle (Chelmsford). Three or four good observations compared together by Captain Tupman.	55 miles over Stoke Ferry, Norfolk.	36 miles over Stratford-on-Avon.	100 miles in three seconds by two estimates of the duration. Velocity 33 miles per second. (Parabolic speed 35 miles per second.)	112+27; between β and ι *Geminorum*. All the observed paths conform to it very nearly.	108+28, Dec. 9, 1877, Corder. A sharply defined radiant of streak-leaving meteors (of which this was one) apparently not Geminids, with long courses, not visible with the Geminids at 107+35 on the 10th.
1878, March 25, 10^h 22^m a.m. Large meteor in sunlight; conical, white, with red tail; burst, and left a smoke-wreath visible for 10^m or 15^m.	Dunbar, Dundee, &c., East coast of Scotland; and North of England.	50 miles; 30 miles E.S.E. from Berwick.	22 miles; 45 miles E.N.E. from Aberdeen.	130 miles in about 4 seconds (or 33 miles per second); not very certain estimations. (Agrees with the parabolic velocity.)	332–20 (±5°); near ν *Aquarii*; 8° south of the ecliptic, and preceding the Sun's place 32° in R.A.	Very bright, near Dundee, even when passing close to the Sun. The perihelion distance of the real orbit is very small, = 0·02.

1878, April 2, $7^h\ 54^m$ p.m. Detonating fireball; ½ Moon's diam.; red; slow, halting motion; burst into fragments.	Blackheath, Birmingham, and Leicester. Calculated path by Captain Tupman and Professor Herschel.	60 miles; 10 miles S. from Leicester.	15 miles (end-height very well determined); 5 miles W. from Coventry, 35 miles (agreeing with the time interval of the sound) from Leicester.	50 miles (beginning and length of path not very certain) in 3 or 4 seconds. (Agrees with the parabolic speed of 13 miles per second.)	177+49 (±3°); near χ *Ursæ Majoris*.	180+49, April 1–15, Heis, M. 7. A principal radiant of the April Ursids, whose streams are all nearly anti-apical.
1878, May 12, $8^h\ 53^m$ p.m. ¼ Moon's diam.; white, leaving sparks and a fragment near its disappearance. A detonation heard at Galashiels.	Edinburgh and the neighbourhood, in Scotland; York, and the North of England.	78 miles over Northallerton, Yorkshire.	17 miles over Boness, near Edinburgh; passing at a height and distance of about 34 miles nearly over Galashiels.	155 miles in about 10 seconds, reckoned, from several good estimates, for the whole flight. The parabolic velocity is 15 miles per second.	214–7 (±4°); near ι *Virginis*.	210–10, May, Denning 47 (1877), a rich, new shower. [Forshey, April 18, 1841, 198–8; exact radiant of a bright meteor shower. (*Am. Jour. of Sci.* vol. xlii. p. 395.)]
1878, June 7, $9^h\ 53^m$ p.m. ¼ Moon's diam.; blue, with reddish, flickering tail, and long, slow flight; left no streak.	South-western part of England; London, Kent, Shrewsbury, &c.	65 miles; 20 miles W.N.W. from Guernsey, Channel Islands.	37 miles; 15 miles E.N.E. from Lundy Isle, Bristol Channel.	160 miles in 8 or 9 seconds (by one good and several other estimates). Velocity about 19 miles, parabolic speed 20 miles per second.	247–25 (±5°); close to *Antares*.	248–20, fireball of June 17, 1873, Galle and von Niessl.
1878, July 29, $9^h\ 25^m$ or 30^m p.m. ⅛ Moon's diam.; vivid white flash, and long spark-track; bursting at last; motion swift.	Manchester, Lancaster, and N. Wales and Cumberland.	82 miles; 8 miles W. from Manchester.	20 miles; midway between Preston and Blackpool, coast of Lancashire.	70 miles in about 3 seconds, by two estimates reckoned for the whole course. Velocity about 23 miles, parabolic speed 21 miles per second.	290 + 42 (or between 285+45 and 300+35, from the best recorded tracks); near δ *Cygni*.	284+44, end of July, 1878, Denning. A radiant point of some bright meteors.
1878, Aug. 11, about $10^h\ 10^m$ p.m. ¼ diam. of and outahone full Moon; greenish; burst into three red fragments, and detonated.	Bloomington, Indiana; Virginia and Pennsylvania. Notice and calculation of the meteor's path by Professor Kirkwood.	About 77 miles over the northern part of Western Virginia (350 miles due E. from Bloomington, alt. 10°).	15 or 20 miles (?) over Crawford County, Pennsylvania. Distance (by interval of the sound) west of Titusville, in that county, 25 miles.	About 170 or 180 miles in two seconds (an "uncertain" estimation); motion swift, and apparently hyperbolic (?).	Nearly horizontal and due south. But an exact position of the radiant point cannot be indicated.	*The Analyst*, U.S. Journal of Mathematics, vol. v. p. 178, Iowa, 1878.—The observations are few and incomplete, but difficult to reconcile with a parabolic speed of 20 miles (*circa*) per second.
1878, Nov. 18, $9^h\ 50^m$ p.m. A fine, slow-moving meteor, as bright as *Jupiter* or *Venus*.	Bristol and Writtle (Chelmsford). Real path calculated by Captain Tupman and Professor Herschel.	70 or 80 miles; midway between Nantes and Angers, France.	45 or 50 miles; midway between Le Mans and Laval, France.	About 70 miles. The duration of the meteor's flight was not recorded.	354+1, at λ *Piscium*. [The radiant point of 8 1743 I. (Clausen's) is in this constellation from the middle of the month of November to that of February.]	350+2, Dec. 1–2, 1877, Denning. A radiant of several slow meteors, one of them a fireball. 4+4, December, Schmidt.

agreement much more certain than any which are presented in the list would evidently be required, before even the best examples which it affords could fairly be produced as certain cases of new discoveries of cometary meteor showers.

Among the meteor systems thus found to accompany the April Lyrids, Mr. Denning notices several reliable centres, and some suspected ones in the circumpolar constellations eastward from *Lyra*, of *Cassiopeia*, *Perseus*, *Auriga*, and *Camelopardus*, &c. A suspected shower of this group near *ε Cassiopeiæ* (19+59, a point at *ιδα* of the same constellation having been already identified in March and April as a meteor-apex by Mr. Greg), coincides almost exactly with the observed direction (from 18+57) of two detonating fireballs seen in Austria and Bohemia on April 10, 1874, and April 9, 1876, as obtained by Professor von Niessl from careful investigations of their real paths.*

Mr. Denning and Mr. Corder also recorded, in April and May 1877, a well-marked and pretty active shower of bright meteors at about 207−8, between the stars *Spica* and *ι*, *ε Virginis*, a radiant point which is nearly on the ecliptic, and which also coincides very nearly (as was originally remarked by Herrick) with the Earth's anthelion, or antisolar point at the time of the appearance. Two notable and well-determined meteor radiant points in April and May, near the ecliptic and to the stars *α*, *ι Virginis*, have been recorded very close to this place, of which the possible accordances with this newly observed, pretty rich, and apparently long enduring meteor shower may either be accidental or will perhaps hereafter receive some more distinct corroborations from further observations. A shower of 60 reddish, moderately bright, slow moving shooting stars, appearing in two and a quarter hours, was seen in America on the night of April 18. 1841, by Professor Forshey, who first noticed their frequency at about $8^h\ 30^m$ P.M., and who determined the exact place of their radiant point, not quite halfway from *Spica* towards *θ Virginis* at 198−8. The tracks of all but five of these sixty shooting stars diverged with deviations of less than 10° from a common centre at this place, the meteors leaving no streaks, and resembling each other in all respects very closely, although quite different in their general appearance from the swift streak-leaving members of the well-known August meteoric shower.† Another approximate agreement with the direction of the April

* *See* the last Annual Report in these *Notices*, vol. xxxviii., p. 223. Von Niessl's first rough position, near *ε Cassiopeiæ*, is there given as the approximate direction of the calculated paths; but the place at 18+57, found at last, coincided, it now appears, more exactly with the position, as described above, of the star *δ Cassiopeiæ*.

† Briefly extracted from a notice of the shower, with some remarks on its appearance, by E. C. Herrick, in the *American Journal of Science*, vol. xlii., p. 395, April–October, 1842. A radiant point of some bright meteors, on April 10, 1864, was also noticed by Professor Herschel, near *δ Virginis*, confirming Heis, at 192+4; these *Notices*, vol. xxiv., pp. 213–215.

"Virginids" is that of the real course and radiant point of the detonating fireball, described in the foregoing list, which burst over the neighbourhood of Edinburgh on the evening of May 12, 1878. There is reason to suppose that this fireball was aërolitic, from the statement that a sound like a deep peal of thunder was heard at Galashiels at an interval of time after its disappearance there corresponding exactly to the distance of its fiery-looking course and passage over the Pentland Hills, about 30 miles from the observer. Its real course to this point, as traced from some well accordant observations, was directed from a radiant point over York and Hawick, at about the altitude 22°, 35° east from south, only the altitude being uncertain to the extent of five or ten degrees. The concluded place of this large meteor's radiant point, at 214−7, is therefore less certain and exact in declination and latitude than in R.A. and in longitude on the ecliptic. But with the above apparent altitude, which accords best with the several combined descriptions, it yet appears to have been not far (6° or 8° north) from the ecliptic, in a degree of longitude 12° or 15° east from *Spica*, and occupying accordingly, near the above noted star-showers' radiant points, a point nearly midway between the stars ι, κ *Virginis*.

Although the true Lyrids were extremely scarce on April 19–20, 1877, Mr. Denning found, from the foreshortened tracks of five or six seen in a watch of about five hours, a very exact radiant point of the shower at 269+35; while, from thirteen tracks recorded in two hours on the same night, Mr. Corder deduced a position at 275+35, agreeing more nearly with the earlier exact determinations of its place at about 277·5+35. The apparent paths of seven Lyrids recorded in about an hour on the morning of April 21, 1869, by the Director of the Urbino Observatory, Professor Serpieri, exhibited a radiant point near the place found by Mr. Denning, at 267+35, as obtained from a projection of their tracks by Schiaparelli, who remarked that this position of the Lyrid centre agrees better than any previous one with the radiant point at 270·4+33·5 of the comet 1, 1861.* In April, 1874, Dr. Weiss, of Vienna, began to collect and compare together recorded observations of the April Lyrids, with a view to extracting, if possible, from the projected paths a place of the meteor radiant point agreeing exactly with the corresponding radiant position of the meteor-comet. A cursory inspection of some of the recorded tracks led him to regard a distinct centre of the shower as possibly assignable at 265+35, in approximate agreement with the cometary place. But the lack of observations of this poorly represented special star shower has scarcely yet permitted the attainment of very positive determinations; and the question of good

* *Bullettino Meteorologico di Urbino*, anno 1869, p. 20. The observation, with the remark by Schiaparelli, is also described at p. 295 of the vol. for 1869 of the *British Association Reports*.

agreement with the comet's radiant point, or of possible oscillations from it at different times, which the radiant point of the April Lyrids may present still eludes satisfactory solution and establishment by such inquiries, from the actual scarcity of observations of its meteors which the absence of strong intensities of its displays since its last maximum appearances in the years 1863–64, has for a long time uniformly prevented observers from collecting in nearly all the later recurrences of its traditionally interesting annual returns.* A shower at 265+38 occurs as nearly the richest of each series in the early April and early May periods of Mr. Denning's admirably arranged and wonderfully copious Catalogue of his reductions from the Italian Meteor Association's Observations of the year 1872. This prominent April and May shower near *θ Herculis* apparently coincides with Schiaparelli's radiant point (SZ. 68) of May 18, at 263+38. Later showers in Schiaparelli's list (SZ. 75, May 25, 277+39, and SZ. 79, June 14, 280+35) are noticeable in the same neighbourhood, the latter agreeing with showers of Schmidt, Greg, and Tupman in June, and being identified (at 285+32, on June 15–17)† by one of two positions only which Mr. Denning's list contains, of meteor showers that he observed in June. A shower at 258+37 was also among those which he observed in the year 1877 towards the middle of July.

The commonly supposed adherence of meteors and meteor showers for very great lengths of time to nearly fixed radiant points or average directions of their streams, to whose fancied rule of fixity these meteor showers in April to July, nearly concentric with the April Lyrids, seem to offer no exception, is more abundantly illustrated by many examples occurring in Mr. Denning's extensive Catalogue of his Italian meteor shower reductions (which contains about 180 primary or distinct positions, and about 135 others nearly identical with them in one or more adjacent months) than in any former Catalogue of individual

* *The Reports of the British Association*, vols. for 1863, p. 325, and 1864, p. 98, and for some later years, contain some fragmentary descriptions. But the particulars of the abundant shower of April 21, A.M., 1863, were not dwelt on, from their length, in that year's Report, and it does not now appear probable that any good additional information regarding the appearance of that very notable star shower could be recovered for examination.

† Another example of very close corroboration of one of Schiaparelli's showers (SZ. 123, July 30, 345+40, forming the last of a "Lacertid" group at about 337+41), is the observation by Mr. Hind on August 2, 1875, of a marked shower with a most decided radiant point at *o Andromedæ* (344+41·5). The place of Schiaparelli's shower was by some confusion given wrongly as 335+40 in a notice of this observation at p. 216, vol. for 1875, of the *Reports of the British Association*; and again its No. as 135, and the place of Mr. Hind's shower as 340+42 in Professor Herschel's list of comet and meteor shower accordances, these *Notices*, vol. xxxviii., p. 384. The first of Schiaparelli's four "Lacertid" showers (SZ. 98, July 18, 332+35) was well confirmed last year by a good view obtained on July 25, 26, 1878, by Mr. Denning of a rich meteor stream with a very exact radiant point near *a Lacertæ*, at 332+37.

showers. The well-known meteor origin of the August Perseïds thus also remains in distinct and apparently never entirely suspended activity at a nearly fixed focal point during all the months from July to December. But the orbits both of the Perseïds and of the April Lyrids are well known to be prodigiously long ellipses; and as orbits of that form, of these long enduring concentric meteor showers, are at the beginning and end of the long periods of their durations (and often in a much shorter space of days in many cases) almost the antipodes of each other in their figures and positions, it would at present be taking too confident, although perhaps not an impossible view of their past history and derivation to regard as proceeding by easy variations from a single original source or datum channel, orbits of such vast lengths and periods, the spheres of whose revolutions now lie in tracts of space apparently quite incongruous, and so singularly remote from each other in their distances and directions. Determinations of the dates of maximum, and of more precise durations and centres of radiation of nearly coincident meteor showers, so as, if possible, to separate from each other overlapping meteor systems, appear accordingly in the recent great advances of our knowledge of the numbers and diversities of ordinary meteor streams, to be the best and most certainly effective means of arriving, by the help of continued observations, at a true solution of this interesting and by no means simple and very readily comprehended question.

The later showers of the year observed in 1877, and described by Mr. Denning in his list, include a large number of well determined radiant-point positions, often well marked on special nights, forming, together with the earlier observations of the year, a large and most invaluable collection. Only a few of its latest and more conspicuous determinations have already been noticed (in the last of these Reports); while, from the numerous exact positions now clearly set forth, and individually described, a much larger selection of such important points for future verification might very easily be extracted; but their minute details, and the somewhat excessive length to which this review has already extended, will not permit their recapitulation here, to invite observers more expressly in the course of future years to devote to the many well-marked showers and conspicuous observations which the list contains the amount of active attention and vigilance which they will require to reaffirm them, and corroborate them, and if possible to extend their indications.

One of the results obtained by Mr. Denning's observations in 1877, which may perhaps assist to explain the long observed duration of the August Perseïds, was the detection in July of two radiant points near the stars θ, and a, κ Persei distinct from each other and from the true radiant point of the Perseïds of August 10. The shower near θ (D. 1877, 64) Mr. Denning found to be confirmed by his Italian reductions; and a very remarkable

proof of its separate existence, with a precise determination of its date and radiant point, was obtained last year by Mr. Denning's observation on the night of July 31, 1878, and on a few immediately adjacent nights, of an abundant shower of streak-leaving shooting-stars resembling the true Perseïds in all respects excepting in the shortness of their courses, with a radiant point about 3° south of the cluster χ *Persei*, and scarcely six or seven degrees distant from the focus of the August Perseïds, at 33+52. Forty-four meteors proceeding from this point (or Perseïds II., as they are now denoted) were recorded on the nights of July 30–August 1, with a strong maximum of their numbers (21 meteors) on the night of July 31. Only five or six true Perseïds (or Perseïds I.) were at the same time visible on those nights; while on August 7 and 8, when the sky was again clear enough for observations, the shower of Perseïds II. had ceased entirely, and the true Perseïds with their usual radiant point were only just beginning to be visible in some abundance. The new shower was not distinguishable before July 21, although fifty-nine of its meteors were afterwards recorded; and it was thus of very brief, although of remarkable, activity during the short period of its soon following maximum display. It coincides closely in its radiant place with that of a shower at 31+55, noted as "exact" by Schmidt for a period of a little later date, between August 3 and 12.

A not less well-defined and conspicuous star shower was, at about the same time, observed by Mr. Denning, on the nights of July 26–30, 1878, producing on those nights fifty fine train-less slow moving meteors, with long courses from a very exact radiant point near $\dot{c}$ *Aquarii*, at 341—13; eight of these meteors in three quarters of an hour before midnight on July 30 being seen diverging from the radiant point which was then hardly risen, or but just rising, near the east horizon; and of the rest, which were visible on that and the earlier nights, twenty-two were recorded on July 27.* On the night of July 31, however, among nearly one hundred meteor tracks recorded, only two or three belonged to this fine and active shower, which therefore appears to have reached a maximum of its bright, shortlived display in the interval between the dates of July 27 and 30. An almost identically similar observation of this shower was made on July 27–31, 1870, by Captain Tupman, and its appearance about the end of July and the beginning of August has been noted independently by Heis, Neumayer, Schmidt, and Weiss, at points coinciding evidently among several known contemporaneous ones in *Aquarius* with this one of greatest note and prominency in that constellation. A bright and conspicuous star-shower occurring three months earlier, near α *Aquarii*, in this region, was observed by Captain Tupman on April 29–May 2, 1869–70, and to this important star shower

* *Nature*, vol. xviii., p. 356.

and to its new and accurately defined successor in *Aquarius*, both of them very distinctly described by Captain Tupman, the distinguishing titles of "May 1 Aquariads" and "July 30 Aquariads" may now very appropriately be assigned. As a shower of special date, and of frequently observed recurrence, future watches for the July 30 Aquariads, as well as for the new minor Perseïd system just described, will hereafter be as desirable and as needful to trace the degree of annual regularity or the intermittences of their returns as the watches for the Lyrids, Geminids, Orionids, and Taurids, which have been kept continuously with pretty successful vigilance for this purpose during recent years.

Three long-pathed meteors of the May 1 Aquariad shower were mapped at Writtle on May 4, 1878, by Mr. Corder, giving a position of the radiant point eight or ten degrees of right ascension in advance of the exact place found by Captain Tupman, at 334−1. Although this place and the date are both in better agreement than those of the main shower with the theoretical radiant point at 337, 0, of a meteor shower from Halley's comet at the point of its closest approach, about May 4, rather near to the Earth's orbit, yet its late hour of rising and the quickly approaching dawn, coupled with obstinately cloudy skies, have for so many years prevented a good view of this shower from being seen, and good positions of its radiant point from being obtained, that nothing confirmatory of a possible cometary origin of this meteor shower has yet been ascertained by observations. Mr. Corder also noted eleven Lyrids on April 20, 1878, with a radiant point at the same place, 275+35, as that which he observed in 1877.* Mr. Denning's observations at Bristol included thirteen Lyrids on April 20–22, the radiant of the shower being well defined at 272+32, and the appearance of a few of its meteors on April 22 being unusually late indications of its continuation on a date generally conspicuous hitherto for the total termination and expiration of the Lyrid meteor stream.†

Of the other major star showers of the past year, a generally good view was obtained of the Perseïds I. on the night of August 10, 1878, although in the strong moonlight, which lasted until nearly daybreak, its smallest meteors were invisible, and the sky was everywhere overcast on the nights of August 9 and 11. The horary number seen at Bristol and at Writtle was, at its maximum between 14^h and 15^h, about 55 conformable and 15 unconformable meteors, a number slightly less than that observed by Mr. Denning at the corresponding time, and in an almost equally favourable state of the sky, on August 10, 1877. The intensity of the shower was therefore not more considerable than it had remained previously for the last few years, and only

* The *Observatory*, vol. ii., p. 103.

† *Ibid*, p. 71; and the above quoted paper by Mr. Denning, in these *Notices*, "On the April Lyrids &c."

observing the appearance of a single meteor. Mr. E. F. Sawyer relates, at Boston, that he descried one Andromede in three hours' watch on the 23rd, and two Andromedes in four hours on the 26th, but none in about ten hours' watch on November 24, 29, and 30, the other November nights of the shower being overcast.* So far as can be ascertained, the cluster of these meteors appears not to have been encountered by the Earth during its passage across their path in November 1878; but it should be borne in mind that a favourable time for its appearance, and for a reobservation of the meteor shower, may be pretty certainly expected to occur again between the 23rd and the 30th of November in the present year.

Scarcely any Geminids were seen in December, full moonlight and the heavy storm of frost and snow which prevailed on the principal nights of their annual return having entirely prevented observations. The shower of the Quadrantids of January 1–2 was seen in clear sky at Newcastle-on-Tyne, by the writer of this notice, on the evening of January 1 and morning of January 2, and again with almost equal brightness on the evening of January 2, 1878, producing eight or ten fine shooting stars per hour, in each watch, of which the apparent paths were not, however, mapped or noted. At Bristol Mr. Denning traced the tracks of fourteen Quadrantids; and of no other shooting stars seen in a sky about one-third part clear between $6^h\ 15^m$ and $6^h\ 35^m$ A.M. on the latter morning, with a radiant point of the shower at 230+51, clearly showing a great activity of the shower, and a brightness of its display perhaps not much inferior to that of its appearance in January 1878.

* The *Observatory*, vol. ii., p. 339.

Papers read before the Society from February 1878 to February 1879.

1878.

Mar. 8. On a new Variable Star in the constellation *Ara*. J. Tebbutt.

On certain groups of Stars with common proper motions. Prof. T. H. Safford.

On the solution by trial of Lambert's theorem in Olbers's method for the computation of parabolic orbits. R. H. M. Bosanquet.

Observations of Occultations of Stars by the Moon, and of phenomena of *Jupiter's* Satellites made at the Royal Observatory, Greenwich, in the year 1877. The Astronomer Royal.

On the Telescopic Observations of the Transit of *Venus*, 1874, made in the expedition of the British Government, and on the conclusion to be deduced from those observations. E. J. Stone.

Radiant Points of Shooting Stars from the Italian observations in 1872. W. F. Denning.

Observations of Shooting Stars in 1877. W. F. Denning.

On the proper motion in Right Ascension of 92 *Draconis*. A. W. Downing.

On the supposed influence of a mass of brickwork upon the errors of a Transit Instrument in its neighbourhood. J. T. Plummer.

Galileo's Trial before the Inquisition in the light of recent researches. Sedley Taylor.

List of known accordances between Cometary and observed Meteor Showers. Prof. A. S. Herschel.

Ephemeris for physical observations of *Jupiter*, 1878. A. Marth.

On Hansen's terms of long period in the Lunar Theory. E. Neison.

On Mr. Stone's note in the January number of the *Monthly Notices*. R. A. Proctor.

On the determination of the axial position of *Mars* with respect to the Earth at any epoch. R. A. Proctor.

Ephemeris of *Mars* for the Opposition of 1877. D. Gill.

April 12. On the duration of Meteor Showers. R. P. Greg.

The luminous spot on *Mercury* in Transit. B. G. Jenkins.

A Comparison of the observations of contact of *Venus* with the Sun's limb in the Transit of 1874, December 8, made at the Royal Observatory, Cape of Good Hope, with the corresponding observations made at the stations in the Parliamentary Report, and a discussion of the results. E. J. Stone.

Photography at the least refrangible end of the Solar Spectrum. Captain Abney.

Observations of the companion of *a Canis Majoris* with the Transit Circle of the U. S. Naval Observatory. J. R. Eastman.

Early Transits of *Mercury*. Rev. S. J. Johnson.

Observations of polar and equatoreal diameters of *Mars* near Opposition, 1877. R. L. J. Ellery.

Note on the table, page 70. vol. ii., of *Dun Echt Observatory Publications*. Lord Lindsay.

May 10. *β* Leonis and B.A.C. 3992. S. W. Burnham.

The Transit of *Mercury*, May 6, 1878. G. F. Chambers.

The Transit of *Mercury*, May 6, 1878. C. L. Prince.

Observations of the Transit of *Mercury*. 1878, May 6, made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

The April Lyrids and contemporary Meteor showers. W. F. Denning.

The Transit of *Mercury*, 1878, May 6. Prof. C. Pritchard.

Observations of the Transit of *Mercury* 1878. May 6, made at Antwerp. Baron von Ertbon and MM. de Boë and Schleusner.

Observations of Ingress during the Transit of *Mercury*, May 6, 1878. F. C. Penrose.

The Transit of *Mercury*, 1878. J. Brett.

Observations of the Transit of *Mercury* of 1878, May 6. A. C. Ranyard.

Note on the comparative brightness of the different parts of the disk of *Venus*. A. C. Ranyard.

The Transit of *Mercury*, May 6, 1878. R. A. Proctor.

Note on the duplicity of the companion to *Rigel*. S. W. Burnham.

Observations of the Transit of *Mercury*, May 6, 1878. J. J. Cole.

On the heat of the Stars. J. J. Waterston.

June 14. On the position of *λ Ursæ Minoris*. Prof. T. H. Safford.

Observations of the Transit of *Mercury*, May 6, 1878, at Princeton, New Jersey. Prof. C. A. Young.

On the late Opposition of *Mars* (extract from a letter to the Astronomer Royal). Maxwell Hall.

Observations of the Transit of *Mercury*, 1878, May 6 (extract from a letter to the Astronomer Royal). Maxwell Hall.

On the spectrum of the New Star in *Cygnus*. T. W. Backhouse.

On the measurement of the inequality of the pivots of Transit Instruments by means of the Spherometer-Caliper. Prof. W. Harkness.

A reply to Mr. Proctor's note in the March number of the *Monthly Notices*. E. J. Stone.

Observations of the Transit of *Mercury* made at the Allegheny Observatory. S. P. Langley.

New Double Stars. S. W. Burnham.

Note on the great Comet of 1861. J. Tebbutt.

On the Atmosphere of *Mars*. R. S. Newall.

On a Solar Thermometer Couple to measure the radiant force of daylight. J. J. Waterston.

Transit of *Mercury*, May 6, 1878. J. I. Plummer.

Note on the Belgian observations of the Transit of *Mercury*. Capt. W. Noble.

On the mean Solar Parallax as derived from the observations of the Transit of *Venus*, 1874 (communicated by the Astronomer Royal). Capt. G. L. Tupman.

Observations of the Transit of *Mercury*, May 6, 1878, at Dun Echt Observatory. Lord Lindsay and Dr. R. Copeland.

Ephemeris for finding the position of the Satellite of *Neptune*. A. Marth.

The proper motions of certain Stars in the Greenwich Seven Year Catalogue for 1864. A. W. Downing.

Spectroscopic results for the motions of Stars in the line of sight, made at the Royal Observatory, Greenwich. III. Communicated by the Astronomer Royal.

On the existence of bright lines in the Solar Spectrum. W. H. M. Christie.

The Transit of *Mercury*, 1878, May 6. N. de Konkoly.

On some terms of long period in the mean motion of *Mars*. E. Neison.

Note on a remarkable property of the analytical expression for the constant term in the reciprocal of the Moon's radius vector. Prof. J. C. Adams.

On the Photographs of the Transit of *Venus* (communicated by the Astronomer Royal). Capt. G. L. Tupman.

Nov. 8. Note upon the proper motion of 5 *Serpentis*. T. H. Safford.

Transit of *Mercury*, May 6, 1878, observed at Cadiz. A. T. Arcimis.

Discovery of Encke's Comet. J. Tebbutt

Additions to the theory of the Sidereal System. Maxwell Hall.

Measures of the B Line in the spectrum of a high Sun. Prof. C. P. Smyth.

Double Star observations made in 1877–78 at Chicago with the 18½-inch Refractor of the Dearborn Observatory. S. W. Burnham.

Account of additional buildings and proceedings at the Oxford University Observatory. Prof. C. Pritchard.

Observations of the periodic Comet of Tempel, 1878. Prof. C. Pritchard.

On Newcomb's correction to Hansen's value of the secular acceleration. E. Neison.

The total Eclipse of the Sun, July 29, 1878. F. C. Penrose.

Some remarks on the total Solar Eclipse of July 28, 1878. A. Schuster.

On the progress of the reductions in connection with the Ascension Expedition. D. Gill.

The Solar Eclipse of July 29, 1878. Prof. H. Draper.

Note on some remarks by Mr. Maxwell Hall on the Opposition of *Mars*. D. Gill.

Note on the presence of particles of Meteoric iron in the atmosphere. A. C. Ranyard.

On the results of the Meridian observations of the *Mars* comparison stars. D. Gill.

Note upon the star Bradley 2935. Prof. T. H. Safford.

On a portable Star Finder for altitude and azimuth telescopes. E. H. Liveing.

Dec. 13. Note on a Determination of the Mass of *Mars*. The Astronomer Royal.

On a new variable star, ι *Andromedæ*. J. E. Gore.

Total Eclipse of the Sun, July 29, 1878. W. H. Pickering.

Measure of the diameter of *Mercury* made at the Princeton Observatory, May 6, 1878. Prof. C. A. Young.

On the Conjunction of *Mars* and *Saturn*, 1879, June 30. Astronomer Royal.

Note on a phenomenon seen in the occultation of a Star at the Moon's bright limb. W. H. M. Christie.

Phenomena of *Jupiter's* Satellites, 1877–78, observed at the Stonyhurst Observatory. Rev. S. J. Perry.

Addition to the paper on the mass of *Mars*. The Astronomer Royal.

Reduction of the north polar distances of the Cape catalogue for 1860 to Auwers' standard. A. W. Downing.

On a variable Diaphragm for use in solar and sidereal observations. F. W. Levander.

A complete general solution of the problem of disturbed elliptic motion. E. Neison.

Notes on the late Admiral Smyth's "Cycle of Celestial Objects," vol ii., commonly known as the Bedford Catalogue. H. Sadler.

On Observations of α *Centauri* made with the Heliometer at Ascension in 1877. D. Gill.

On the visibility of Stars in the *Pleiades* to the naked eye. Prof. Winnecke.

Note on some hitherto unnoticed features near the lunar crater *Hyginus*. Lord Lindsay and Dr. Copeland.

1879

Jan. 10. Observations of occultations of stars by the Moon and of phenomena of *Jupiter's* Satellites made at the Royal Observatory, Greenwich, in the year 1878. The Astronomer Royal.

On the practical advantages of Hartnup's method of testing Chronometers. A. E. Nevins.

On the observed errors of Bouvard's Tables of *Saturn*. E. Dunkin.

Note on *Hyperion*. Prof. A. Hall.

Observations of the Transit of *Mercury*, May 6, 1878, and of the occultation of *Mars* by the Moon, June 3, 1878, made at the Glasgow Observatory. Prof. R. Grant.

On the reduction of the north polar distances of the first Melbourne general catalogue for 1870 to Auwers' Standard. A. W. Downing.

Ephemeris for determining the positions of the Satelllite of *Uranus*, 1879. A. Marth.

Notes on Meteors observed November 27, 1878. Lord Lindsay and Dr. Copeland.

List of Public Institutions and of Persons who have contributed to Library &c. since the last Anniversary.

Her Majesty's Government in India.
Her Majesty's Government in Australia.
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Italian Spectroscopic Society, Palermo.

Astronomische Gesellschaft, Leipzig.
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ADDRESS.

Delivered by the President, Lord Lindsay, on Presenting the Gold Medal of the Society to Professor Asaph Hall, U.S. Navy.

Your Council has this year awarded the Gold Medal of the Society to Professor Asaph Hall

For his discovery and observations of the satellites of *Mars*, and his determinations of their orbits.

It has been usual for your President to state the reasons which have influenced the Council in their awards, and to give a brief history of the discovery, or research, which they have held worthy of such high esteem, and, in following the example of my predecessors in office, I would crave your indulgence if I slightly deviate from custom in one particular.

I allude to some of the work of your Medallist which had rendered his name already familiar at the time he announced his great discovery to the world.

An examination of the writings of Professor Hall show that there are but few departments of astronomy to which he has not paid some attention, combining the skill of the observer with the labours of the mathematician.

From 1858 to the present time almost every volume of the *Astronomische Nachrichten* contains notices of his zealous observation of minor planets and comets. Not content with mere observation, he has in many cases given ephemerides, and has calculated elements, among which may be noticed those of (60), (66), (73), (81), (124), all of them refined pieces of work based on normal places, and in some instances taking into account the perturbations due to *Jupiter* and *Saturn*.

The early history of Mr. Hall affords a bright example of what perseverance and determination may effect in overcoming even the most adverse circumstances.

Born at Goshen on October 15, 1829, Mr. Hall received his early education at the hands of his father and at the village school. In 1842 he was left an orphan, and from comparative affluence he was reduced to work for his living. He served for some time as an apprentice to a carpenter, devoting his leisure hours to the study of geometry and algebra.

In 1856 he studied one term under Brünnow at the Michigan University, whence he went to Cambridge, Mass., and entered the Observatory under Professor W. C. Bond. He applied himself with the greatest diligence to all matters connected with the Observa-

tory, as he was determined—to use his own words—to make himself so useful that they would not care to let him go. Strong and in good health, he found time to study, and worked hard on orbits and the theory of perturbations. He remained at Cambridge until August 1862, when he was appointed one of the aids in the Naval Observatory, Washington, and in May the year following he was commissioned Professor of Mathematics.

In 1863 he published a Memoir on the Solar Parallax deduced from observations of *Mars*, with equatoreal instruments, made at Upsala, Santiago, Washington. Combining all the results, he found,

From Upsala and Santiago	$\pi = 8{\cdot}859''$	$w.$ 43·81
Washington and Santiago	$\pi = 8{\cdot}810''$	$w.$ 24·60,

with the concluded result of all the observations of *Mars* in 1869,

$$\pi = 8{\cdot}8415''.$$

This Memoir he supplemented in 1866 by an examination of 1181 observations used for the parallax determination, and showed conclusively that the method of observing the planet on two wires sufficiently wide apart to cut off small segments of the planet's disk is far preferable to the method of tangents.

In a Memoir communicated to the *Astronomische Nachrichten*, No. 71, p. 191, on the "Positions of the Fundamental Stars," he offers some very sound suggestions, considering that these determinations should be made a *special problem*, to which the undivided attention of the observer should be given. He considers that the instrument should not exceed 5 inches aperture, with circles not greater than 30 inches, and that the objectives and oculars should be interchangeable, in order to eliminate as far as possible constant errors and flexure. Each series of observations should be made by a single observer, who should be an experienced astronomer. He goes on to show, if the number of stars were small, limited perhaps to the 47 chief stars of the *Berliner Jahrbuch* with the addition of a few circumpolar stars, that their positions might be advanced to a degree of accuracy almost hopeless under the present methods of observing.

Your Medallist this year (1868) made a remarkable observation of an occultation of *Aldebaran*, the immersion of which was seen at $0^h\ 3^m\ 10^s{\cdot}6$ Washington mean time. The Moon was invisible at the time and the star was only 8° 12′ from the Sun's centre. This occultation, though given in the *Jahrbuch* and in the *Monthly Notices*, was not in either the American or English *Nautical Almanacs*, nor in the *Connaissance des Temps*.

Professor Hall was sent by his Government to observe the solar eclipses of 1869 and 1870, and though his notes on these observations are interesting, I will not dwell upon them, as they will be fully treated in vol. xli. of your *Memoirs*.

In 1870 he sent an interesting paper to *Silliman's Journal* on the secular perturbations of the planets.

Following the steps of Lagrange, he points out, as had been already done by Leverrier, that the final equations from which the secular perturbations are derived rise to the degree denoted by the number of planets considered and in our system will be of the eighth degree. The conditions necessary for the stability of the system are, first, that the eight roots of the equation for "g" (on which depend the excentricity and the longitude of the perihelion) shall be real and unequal, in order that there may be no terms, outside the circular functions, containing the time as a factor or exponent, which therefore would increase indefinitely; and, secondly, it is necessary that the coefficients, determined by the initial values of the excentricity and perihelion, may not be great, in order that the excentricity may not increase so as to render divergent, the series, which have been assumed in the solution to be rapidly convergent.

When it is required to compute for very remote epochs, he shows that the value of the coefficients of "g" which are multiplied by the time must be very carefully considered. These depend on the values of the assumed masses of the planets, and are usually determined by neglecting terms of the third order.

Leverrier shows that the terms of the third order may produce corrections of the values of "g" amounting to three or four-tenths of a second; probable uncertainties in the assumed values of the masses of the planets may give rise to errors of nearly two tenths of a second. Thus it is evident that for remote epochs calculations must be untrustworthy, since when the time is great the errors in the value of "g" may completely change the character of the circular functions.

Professor Hall next points out that, to obtain satisfactory solutions to the problem, our knowledge of the planets' masses must be greatly increased.

Assuming that in time the masses of *Mars* and *Jupiter* will be accurately learnt from the theories of some of the minor planets, he considers that we have to our hand the instrumental means of making accurate determinations of the masses of *Saturn*, *Uranus*, and *Neptune* by a more complete investigation of the theories of their satellites.

Now follows the only passage I have found in which I cannot entirely agree with your Medallist. He says:—"When the novel and entertaining observations with the spectroscope have received their natural abatement, and have been assigned their proper place, it is to be hoped that some of the powerful telescopes recently constructed may be devoted to this class of observation."

The volume of the *Washington Observations* for 1867 contains a valuable catalogue of 151 stars in *Præsepe* whose places Professor Hall determined by comparison with eleven standard stars. The observations were made with the Equatoreal, and

beginning in 1864, were completed in the spring of 1870. In observing, the telescope was clamped in R.A. but free in Decl. The probable errors are $\pm 0^s{\cdot}043$ and $\pm 0''{\cdot}46$. Bright wires and dark field were used throughout, with a power of 132.

In 1871, in *Silliman's Journal*, we have an interesting paper from Professor Hall on the "Astronomical Proof of a Resisting Medium in Space."

Your Medallist shows, from the investigations of Möller and Oppolzer, that the comets of Faye and Winnecke do not by their motions give any indications of the presence of a resisting medium such as Encke assumed to exist.

It is possible that Professor Hall does not dwell sufficiently on the fact that the perihelion distance of Encke's comet is much less than that of either of the others, and that a resisting medium increasing in density in the neighbourhood of the Sun would account for the anomalies in the motion of the comet (Encke's) without affecting Faye's. It would seem, too, that the perturbations of Winnecke's comet have hardly been investigated with all the accuracy required to decide so delicate a question; added to this, the effect of a resisting medium would be much greater on a rapidly moving comet like Encke's. I need hardly say, however, that the whole problem is surrounded with difficulty.

The most interesting paper which Professor Hall has communicated to our Society is to be found in vol. xxxiii. of the *Monthly Notices*; it is on the "Determination of Longitudes by Moon Culminations." He shows here that such determinations are liable to large constant errors. Assuming the telegraphic longitude of San Francisco to be correct (which may safely be done), the determination from 206 Moon culminations was found to be four seconds in error. Treating of the difference of longitude between Washington and Greenwich, he gives the following table:—

Authority.	No. of Culm.	Longitude. h m s	Errors. s
Loomis	150	5 8 9·3	−2·9
Gillis	394	10·0	−2·2
Walker	...	9·6	−2·6
Newcombe	279	11·6	−0·6
Newcombe	163	9·8	−2·4

The conclusions he draws from this investigation are that all determinations derived from Moon culminations, occultations, and solar eclipses give the difference of longitude smaller than the telegraphic value, $5^h\ 8^m\ 12^s{\cdot}2$, which he assumes to be the correct value.

The *Astronomische Nachrichten* for 1875, vol. 86, contains several papers by your Medallist. He proposes to utilise the observations of the minor planets to determine the mass of

Mars. Starting from certain formulæ in the *Mécanique Céleste*, he shows which planets would give the best results. It seems probable that the method has lost little or none of its value by the discovery of the satellites, as it seems to be one of the best for giving an independent value.

In treating the Washington observations of *Flora* (8) in 1873, he refers to the determination of the solar parallax according to the method proposed by Professor Galle, demonstrating that an uncertainty of measurement at either of the stations would vitiate the whole angle. He points out, without attempting to explain, the discrepancies which are found to exist between the Observatories of Lund and Dublin in the *Flora* observations of 1873, which are $-0''{\cdot}055$; $+0''{\cdot}080$; $+0''{\cdot}330$; $-0''{\cdot}816$; and $+0''{\cdot}965$. "Whatever may be the cause of these differences between skilled observers, they tend to cast a doubt on the reality of the small quantities which are found in the investigation of stellar parallax."

On December 7, 1876, your Medallist noticed a bright spot on the ball of *Saturn*; on the next day letters were sent to astronomers in different parts of the country, asking them to assist in observing it. It was last seen on January 2, 1877. He combined eighteen observations thus obtained into nine, from which he found the time of rotation of *Saturn* to be

h	m	s	s	
10	14	23·8	±2·30	Mean time.

Sir William Herschel had found $10^h\ 16^m\ 0^s{\cdot}4$, and concluded that this time cannot be in error so much as two minutes. The greater number of the textbooks had $10^h\ 29^m\ 16^s{\cdot}8$, and, by a strange error, Sir J. Herschel, in his *Outlines*, gives $9^h\ 57^m\ 1^s{\cdot}91$, which is the sidereal time of the rotation of *Jupiter*.

In a general investigation of the problem of the shadow of a planet, originating in a wish to determine the form of the shadow of the ball of *Saturn* on the ring, he points out that in a special case the shadow may be sensibly a straight line.

I have thus very briefly brought before you the labours of Professor Hall up to the time of the important discovery for which your Council has awarded him the Medal, and I will now in a few words refer to the unsuccessful searches for satellites of *Mars* which had been made previously to the opposition of 1877.

In 1830 Mädler searched in vain for a satellite of *Mars* during the favourable opposition of that year, and came to the conclusion that if such a satellite existed, and if it possessed the same reflecting power as its primary, it could not exceed the diameter of some 20 miles, since a larger one could not escape discovery under favourable circumstances.

The instrument employed in this search was of $3\frac{3}{4}$ inches aperture, and was the same he afterwards employed in his lunar work; and though at the time the conclusions thus drawn were considered hardly justifiable still, as time wore on and larger

instruments were employed, Mädler's estimate obtained better consideration.

Professor D'Arrest made a search for a satellite in the year 1864. This was again unsuccessful. In a paper in the *Astronomische Nachrichten*, vol. lxiv., p. 74, D'Arrest, assuming the distance of *Mars* from the Earth to be 0·52 and with an assumed mass for the planet, computed the apparent elongation of a satellite which would revolve around the planet in a given time. Thus he showed that an elongation of 70′ would give the satellite a period greater than the period of *Mars* round the Sun, or in other words, greater than 687 days. From this the inference was drawn that it is useless to search for a satellite at a greater distance than 70′.

There is also another note on this subject which seems to have escaped the researches of your Medallist. It occurs in *Stjernehimlen*, by F. Kaiser, translated from the third Dutch edition into Danish by Mathilde Oersted, with a preface by D'Arrest. *Copenhagen*, 1867.

On page 423, note 7, there is the following remarkable passage, which, though nominally by the translator, was probably inspired by Professor D'Arrest:—

"That up to the present time no satellite of *Mars* has been found may possibly be owing to the fact that such a satellite, from the nature of the case, must be very near to its primary, and that any faint star becomes totally extinguished and rendered invisible in the immediate neighbourhood of the brilliant planet.

"Formerly it was the custom to explain the same fact by the contrary reason, viz. by pointing out how difficult it must be to find a satellite of *Mars* at a possibly great distance from the planet. However, by reason of the planet's small mass, this can by no means be the case."

The failures of distinguished observers almost discouraged your Medallist from instituting a fresh search, and the low declination of the planet gave promise of better results for Observatories in the southern hemisphere. However, calling to mind the great optical power and excellence of the Clark Refractor, and encouraged by his wife, Professor Hall thought that there might be a slight hope remaining for ultimate success.

Early in August the geocentric motion of *Mars* being such as to render the detection of a satellite comparatively easy, the search was commenced in earnest. Commencing with faint objects at a considerable distance from the planet, it was soon found that they were nothing but fixed stars, and on August 10 Professor Hall began to "examine the region close to the planet and within the glare of light which surrounded it." Keeping the disk of *Mars* just outside the field of view, sweeps were made all round the planet; but as the definition was very bad, and (as was afterwards learned) the satellites being very near at the time, nothing was found.

The next night, August 11, the observations were resumed, the same method of sweeping being adopted. At $14^h\ 30^m$ your Medallist made the discovery of the outer satellite, a faint object N.F. He had hardly time to complete the observation of position when fog rising from the Potomac river stopped his work. Until the 15th bad weather hindered further observation, and though search was made at 11^h, it was unavailing, the proximity of the satellite to *Mars* rendering it invisible.

On August 16 the satellite was again found on the north following side of the planet, and the observations of this night demonstrated clearly that it was moving with *Mars*, and that, if a satellite, that it was near one of its elongations. It was on the night following, August 17, that, while waiting for and watching the outer satellite, Professor Hall discovered the inner one, and obtained measures of it when at a distance of about 31″ from the centre of the planet.

The last doubts as to the character of the faint objects thus found having been dispelled by the observations of August 17 and 18, the discovery was officially announced by Admiral Rodgers. The appearances of the minor satellite were most perplexing, and I cannot do better than quote the words of Professor Hall. He says: "Still for several days the inner moon was a puzzle. It would appear on different sides of the planet on the same night, and at first I thought that there were two or three inner moons, since it seemed to me at that time very improbable that a satellite should revolve round its primary in less time than that in which the primary rotates."

To set this point at rest Professor Hall watched the satellite throughout the nights of August 20 and 21, and was satisfied that there was but one inner moon, which performed its revolution in less than one-third of the time of the rotation of *Mars*, a case, as he observes, unique in our solar system.

Such, in a few words, is the history of a great astronomical discovery; and it is satisfactory to think that the United States Government has received a reward already for the enlightened munificence displayed in placing so magnificent an instrument in the hands of one so capable of using it.

Of the many names suggested for these moons, your Medallist selected those proposed by Mr. Madan, of Eton—*Deimos* for the outer, *Phobos* for the inner satellite.

The labours attending this search by no means ceased with the attainment of the object in view. For your Medallist, not merely content to publish his crude observations, has reduced them, and from the results has given the elements of the orbits of the satellites.

It would, perhaps, be well to describe the method of observation at this point. Professor Hall commences by saying that, as the satellites were faint objects and were always immersed in the glare of light surrounding the planet, the observations were made with difficulty.

'The *modus operandi* was as follows :—The disk of the planet was bisected by one wire of the micrometer as nearly as the eye could judge, while the other was laid on the satellite. As it rarely occurred that both planet and satellite could be seen in the field of view together, it was usually necessary to use the slipping piece of the micrometer, the eye-piece being moved to and fro until the two bisections appeared to be satisfactory. Though at first Professor Hall would have preferred to have had a pair of wires inserted, by which small equal segments of *Mars* could have been cut off, in the manner described in his paper to the *Astronomische Nachrichten*, vol. lxviii., p. 235, he was not willing to break in on his work, and he states that experience has given him confidence in the method he adopted.

The observations thus obtained give polar coordinates or the angle of position and distance referred to the centre of gravity of the apparent disk of the planet, involving corrections for differential refraction and for the figure of the true disk.

For the refraction correction the formulæ, given by Bessel in the *Astronomische Untersuchungen*, vol. i., p. 165, have been used; and the formula,

$$m = \frac{8a}{3\pi} \sin \frac{1}{2} \phi^2,^*$$

gives the reduction from the centre of gravity of the illuminated disk to the centre of the true disk.

It will be noticed here that no allowance is made for the varying intensity of illumination of different parts of the disk;

* Where m denotes the distance of the centre of gravity from the centre of the line of cusps,

and ϕ = the angle at the planet;

a = radius of the semicircular part of the disk,

and π = the number 3·14159.

"p" and "s," as usual, denoting the observed angles of position and the distance of the satellite, and "θ" the angle of position of the line of cusps, the errors of p and s arising from the figure of the disk are found by the formulæ—

$$\Delta p = \frac{m}{s} \cos (p - \theta),$$

$$\Delta s = m \sin (p - \theta).$$

A note on this formula was communicated to the Society by Professor Hall and will be found in vol. xxxviii., p. 122, of the *Monthly Notices*. I see that the formula has been there printed

$$m = \frac{8a}{3\pi} \sin^2 \frac{1}{2} \phi$$

for $$m = \frac{8a}{3\pi} \sin \frac{1}{2} \phi^2.$$

any error, however, due to this cause would have contrary effects before and after opposition.

The observations and the corrections thus found, $\Delta\rho$, Δp, $\Delta\rho$, and Δs, are given, and are found to consist of—

For *Deimos*,

52 observations, made on 31 nights, involving 185 comparisons, in position;
50 „ „ 31 „ „ 137 „ in distance.

While for *Phobos* we have

36 „ „ 25 „ „ 123 „ in position;
43 „ „ 25 „ „ 97 „ in distance.

With the exception of three observations of *Deimos*, made by Professors Newcomb, Harkness, and Holden, the whole series were taken by your Medallist.

For convenience in reduction, the times of the observations were then transferred to the meridian of Greenwich, corrected for aberration, and reduced to decimals of a day.

Although many other observations at different Observatories have been made, no series was so complete as that made at the Naval Observatory, Washington; and your Medallist, considering the difficulty of the observations and the probability of each observer having a constant personal error, decided that it would be unwise to throw all the observations at his disposal into one mass; therefore the elements of the satellites are based upon his own observations alone.

The method of computation is as follows:—Taking the observations near opposition and carefully projecting them, he determined the form of the orbits (which were assumed to be circular). The ratio between the axes of the apparent ellipse gives the angle between the line of sight and the plane of the orbit. This, combined with the position angle of the major axis and the place of the planet, gives the inclination of the orbit to the Equator, and also the ascending node on the Equator.

There seems to be an error in the definition of θ at the top of p. 16 of his paper, "Observations and Orbits of the Satellites of Mars &c." Instead of "angle between the orbit plane and the plane perpendicular to the line of sight," we should read "angle between the orbit plane and the line of sight." If this were not so, the formula would run $\cos\theta = \frac{b}{a}$. It will also be perceived that Professor Hall says nothing as to how the approximate period was found. This, however, was probably obtained by combining extreme observations.

From these data he obtained the approximate circular elements, in which

μ is the number of degrees of angular motion in one day.

a the apparent major axis of the orbit seen from a distance unity;

I inclination of the orbits to the Earth's equator
N the longitudes of the ascending nodes } same for both satellites

u the angular distance of the satellite from the node at the epoch.

He then compared the observations with these elements, using Bessel's methods for facilitating the calculation of the positions of the satellites.

He next formed differential equations—98 in the case of *Deimos* and 79 in the case of *Phobos*—for the correction of the following elements:—

The longitude of the node;
The inclination of orbit to Earth's equator;
Longitude at epoch;
Mean angular motion;
Two terms dependent on the excentricity and the line of apsides; and finally, in the case of the distances,
A term dependent on the major axis.

Had this part of the work been carried out in polar coordinates as it was commenced, it would have been perhaps preferable as the more elegant, though in passing to rectilinear your Medallist has followed in the steps of good men, such as Newcomb, von Asten, and Bessel himself.

The coefficients of the equations of condition were computed by Dr. C. Powalky, and were checked by Professor Hall. It will be seen that the normal equations are not given.

The resulting corrections are in general small, the sums of the squares of the residuals being, in the case of *Deimos* 29·07, and for *Phobos* 23·09; whence the probable error of a single observation is found to be, for *Deimos* 0″·391, and for *Phobos* 0″·412.

The excentricity of the orbit of *Phobos* is about $\frac{1}{30}$th, with a probable error of about $\frac{1}{600}$th, and your Medallist most justly concludes that it must be real.

The excentricity of the orbit of *Deimos* is so small that we may consider the circular element of this satellite as practically sufficient for the observations.

An examination of the equations for *Deimos* shows the largest outstanding residuals on August 17. The comparisons and reductions for this date were examined, but no error was found, and your Medallist preferred to let them stand with this remark:—

"The method of rejecting observations after the comparison by means of criterions which are based on the residuals and the probable errors seems to me to rest on a false logic and to lead to the dangerous practice of trimming observations for the purpose

of procuring an apparently accurate result, which, in fact, may be wide of the truth."

The smallness of the probable error of a single observation is the best proof we can have, showing a high degree of accuracy, considering how faint the objects are and under what difficulties the observations were made.

We now come to what may be considered the most important outcome of your Medallist's brilliant discovery, viz. the determination of the mass of *Mars*.

The result he obtains from *Deimos* gives

$$M = \frac{1}{3095313 \mp 3485},$$

and from *Phobos*

$$M = \frac{1}{3078456 \mp 10104};$$

and seeing that these two determinations fall so nearly within the limits of their respective probable errors, Professor Hall has taken the mean by weight as the final result for his observation, thus giving

$$M = \frac{1}{3093500 \mp 3295}.$$

We may assume this determination to be the best in existence, and it may be a matter of interest here to look at the different values which have been from time to time assigned to the mass of *Mars*.

Authority.	$\frac{1}{m}$
Laplace	1846082
Delambre	2546220
Burckhardt	2680337
Airy, 1828	3734602
Hansen, Olufsen	3200900
Leverrier, I	2994790
„ II	2812526
„ III	2948110

Since discovery of Satellites.

Place.	*Deimos* $\frac{1}{m}$	*Phobos* $\frac{1}{m}$
	3054000	
Washington	3095313	3078456
Cambridge, U.S.	3023319	3039643
Glasgow, U.S.	3024348	3400630
Pulkowa	3146996	.....

Laplace, in the *Mécanique Céleste*, gives a value based on the assumption that the mass of the planets varies inversely as their

distances from the Sun. This was afterwards reduced by Delambre. Burckhardt slightly increased the value, which Hansen and Olufsen very greatly decreased in their Tables of the Sun. Le Verrier at different times has used various values for *m*. Commencing with the value given by Burckhardt, he found that it had to be multiplied by the factor 0·895. In vol. iv. of the *Annales de l'Observatoire* he gives a most probable value, and this was again changed in vol. xi. of the same publication.

The determination of this important factor would be materially improved by observations we may hope to make this year, by which a better knowledge of the periodic times of the satellites will be obtained.

Various estimations of the brightness of the satellites have been made, ranging from the 11th to the 15th magnitude in the case of *Deimos*. With respect to *Phobos* much uncertainty has been expressed, but at the same time the opinion seems to be that it is rather brighter than the outer satellite.

Your Medallist mentions having, on August 17, 1877, observed a fixed star which was mistaken for *Deimos*, and thinking that a determination of its magnitude might be of interest to the Society, I requested Dr. Copeland, if possible, to observe it, and I have received the following report:—

January 16, 1879. Altitude of star, 13°±. I noted "Hall's star is about 11½ magnitude, not seen in finders." Stars about 1 m. brighter I could see well in the finder. In the 15¼-inch the star bore illumination of wires well, the place was roughly determined, and agrees with Professor Hall's place within 1ˢ·5 and 1′·1. An accurate reduction will probably reduce this discordance; the more so as the comparison involves a reduction to 1800, in order to use the Berlin Star Map.*

Your Medallist states that this star was a little brighter than *Deimos* at the time he observed it. The above observation is therefore confirmatory of his estimation.

Professor Hall closes his report by giving data for the computation of Ephemerides of the satellites for the present year, when Mars will have a comparatively favourable declination, 18° north. The estimated brightness on October 10 will be 0·63, and on November 4, 0·73, the unit being the brightness on October 1, 1877.

And your Medallist concludes by giving examples of the computation, using the Table prepared for this purpose.

And now, Mr. Hind, may I request you, as the Foreign

* Since writing this I have received another observation of the star, in which the observation note runs thus: "Hall's star is quite 11th mag.; could be well seen when running along the bright wire [of micrometer], which was very well illuminated with the maximum brightness."—R. C., Jan. 27, 1879.

Nothing can be made of the other star this season, as it is hopelessly lost in the twilight. It will be an admirable popular object, as it is only about 7′ or 8′ from a 6-mag. star, and therefore can be readily found with small instruments.

Secretary of the Society, to place this medal in the hands of the Minister of the United States, to be transmitted to Professor Asaph Hall, as the highest mark of esteem in the gift of the Royal Astronomical Society.

Assure him at the same time of the deep interest that we in England have ever felt in watching the progress of our beloved science in the hands of our cousins in the Far West.

The Meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected :—

President.

Lord LINDSAY, M.P., F.R.S.

Vice-Presidents.

J. C. ADAMS, Esq., M.A., LL.D., F.R.S., Lowndean Professor of Astronomy, Cambridge.
Sir G. B. AIRY, K.C.B., M.A., LL.D., D.C.L., F.R.S., Astronomer Royal.
WILLIAM HUGGINS, Esq., LL.D., D.C.L., F.R.S.
WILLIAM LASSELL, Esq., LL.D., F.R.S.

Treasurer.

FRANCIS BARROW, Esq., M.A.

Secretaries.

J. W. L. GLAISHER, Esq., M.A., F.R.S.
A. COWPER RANYARD, Esq., M.A.

Foreign Secretary.

J. R. HIND, Esq., F.R.S., Superintendent of the *Nautical Almanac.*

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Sir EDMUND BECKETT, Bart., M.A., LL.D., Q.C.
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A. A. COMMON, Esq.
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GEORGE KNOTT, Esq., LL.B.
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Captain W. NOBLE.
HERBERT SADLER, Esq.
Captain G. L. TUPMAN, R.M.A.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXIX. *March* 14, 1879. No. 5.

LORD LINDSAY, M.P., F.R.S., President, in the Chair.

Maures Horner, Esq., 15 Bishopsgate Street Within, E.C.;
E. E. Markwick, Esq., East Acton, Middlesex;
Arthur E. Nevins, Esq., 3 Abercrombie Square, Liverpool; and
Charles Clement Walker, Esq., Lilleshall Old Hall, Newport, Shropshire;

were balloted for, and duly elected Fellows of the Society.

Observations of Encke's Comet, 1878.

By J. Tebbutt, Esq.

The positions of Encke's Comet which I now send were determined by me with a ring-micrometer on the 4½-inch Equatoreal. I found it very difficult to observe the comet owing to the absence of a nucleus or other well defined condensation. All I could do was to note the bisection of the comet at the edges of the ring. The larger telescopes of the southern hemisphere will doubtless furnish more accurate places. The comet was first seen by me on the 3rd August, and observed till the 28th; but as it was excessively faint after the 17th, I do not think the positions subsequent to that date will be of any real value. With some few exceptions, in which the correction could not amount to a second of arc, the differential observations have been corrected for refraction, but in every case the proper motion corrections have been applied. The star places derived from the Catalogues of Lalande and Weisse have been brought up to the mean epochs 1839 and 1852 respectively by means of the precessions in the Catalogues, and the precessions recalculated from Professor Peter's constants. By means of these precessions the mean places have been brought up from 1800 and 1825 to the beginning of 1878. In computing the parallax corrections, the log distances from the Earth have been taken from Dr. von Asten's Ephemeris in No. 2197 of the *Astronomische Nachrichten*, and the mean equatoreal horizontal parallax of the Sun has been

adopted 8″·85. In turning the observations to account, it will be advisable to add 7 seconds of time to the longitude hitherto assumed for my Observatory; the longitude will therefore be $10^h\ 3^m\ 23^s$ E.

It appears that during the period embraced by the observations the comet was about 17 seconds of time east, and 3 minutes of arc south of the positions assigned to it in the Ephemeris of Dr. von Asten.

Observatory, Windsor, N.S. Wales,
November 16, 1878.

Apparent Places of Encke's Comet. 1878.

Date August.	Windsor Mean Time. h m s	Comet's App. R.A. h m s	Correction for Parallax. s +	Comet's App. N.P.D. ° ′ ″	Correction for Parallax. ″ +	No. of Comps.	
5	6 29 45	10 16 14·26	0·42	83 42 31·5	4·4	4	1
6	6 50 9	10 23 59·00	0·43	84 52 29·1	4·4	4	2
7	6 46 12	10 31 32·85	0·43	86 1 17·5	4·4	1	3
8	6 38 55	10 39 3·07	0·43	87 8 51·1	4·5	4	4
9	6 45 39	10 46 36·41	0·44	88 17 48·1	4·5	6	5
10	6 41 9	10 54 2·74	0·44	89 25 31·2	4·5	5	6
11	6 42 42	11 1 28·99	0·44	90 33 26·0	4·5	2	7
12	7 7 50	11 9 3·91	0·45	... ...	...	2	8
13	7 3 15	11 16 28·31	0·46	92 49 12·7	4·5	2	9
14	6 56 4	11 23 49·61	0·45	93 54 36·1	4·5	7	10
15	6 56 11	11 31 13·87	0·46	95 0 26·4	4·5	7	11
16	6 51 4	11 38 36·71	0·45	96 5 51·2	4·4	3	12
17	6 59 0	11 46 2·37	0·46	97 10 8·6	4·4	10	13

Mean Places of the Stars of Comparison for 1878·0 *and Apparent Places for the Dates of Observation.*

Star of Comp.	Mean R.A. h m s	App. R.A. s	Mean N.P.D. ° ′ ″	App. N.P.D. ″	Authority for Star's Mean Place.
1	10 16 55·65	57·20	83 41 9·6	17·9	Lalande. No. 20142.
2	10 25 58·38	59·93	84 43 45·1	52·1	Radcliffe Obs. 1872 & 1874.
3	10 37 47·81	49·37	86 8 7·7	15·5	Lalande. No. 20708.
4	10 37 10·00	11·51	87 11 48·0	55·9	Lalande. No. 20697.
5	10 45 57·63	59·18	88 19 40·3	48·7	Wash. Cat. 1845–71. No. 4533.
6	10 56 18·35	19·92	89 26 15·5	24·6	Lalande. Nos. 21183 & 4.
7	11 6 0·38	1·96	90 30 49·8	59·5	Lalande. No. 21429.
8	11 9 34·86	36·44	... ...	...	Weisse XI. No. 127.
9	11 9 58·22	59·78	... ...	...	Lalande. Nos. 21525 & 6.
9	... ...	...	92 48 26·3	36·5	Wash. Cat. 1845–71. No. 4709.
10	11 23 1·28	2·87	93 46 30·8	41·7	Weisse XI. No. 377.
11	11 28 9·14	10·73	94 51 13·3	24·6	Wash. Cat. 1845–71. No. 4829.
12	11 43 1·75	3·37	96 13 4·3	16·3	Weisse XI. No. 726.
13	11 44 57·02	58·64	97 18 43·9	56·3	Wash. Cat. 1845–71. No. 4961.

Remarks on Mr. Sadler's Paper in the January Number of the Monthly Notices. By C. G. Talmage, Esq.

The January (1879) Number of the *Monthly Notices* contains a paper with the title "Notes on the late Admiral Smyth's *Cycle of Celestial Objects*, volume the second, commonly known as the *Bedford Catalogue*."

It is to be remembered that the book commented on is by a past President and Medalist of the Royal Astronomical Society.

The writer of the article commences by saying that, "unless he is mistaken, the Presidential Address is couched in eminently cautious language as to the exactness of Admiral Smyth's work."

As a matter of fact, he *is* mistaken, for in fairness he should have given these words of the Astronomer Royal: "My confidence in the exactness of the observations is purely personal. Knowing the attention which has been given to the instrumental adjustments, the intentness of the observer upon his work, the nerve, which is made steady rather than disturbed by the anxiety to procure a good observation, and the general skill in the management of the instruments, I can truly say that, if an accurate observation were required, I should desire that it should be made by Captain Smyth. . . . . And in presenting the medal, I beg leave to convey with it the expression that never was a medal more worthily earned."

There is not much ambiguity in language like that; and the Astronomer Royal, in a letter to me lately, again says: "I had great confidence in Captain Smyth's observations."

I have received from Professor C. P. Smyth a letter which he has requested me to read to the meeting. It is in part as follows:—

"I am too busy to be able to come to the meeting, and I should probably be esteemed, if present, an insufficiently disinterested speaker. But at this distance I trust I can look on calmly enough at the affair, and certainly should know some useful and necessary data towards understanding it.

"The case begins with the printing and publishing, by the Royal Astronomical Society, of a paper containing, at first sight, merely a list of errata in my late father's old and now long since out-of-print book, *A Cycle of Celestial Objects*.

"If such a list of errata were ably, thoroughly, carefully made, and deduced by its author from his own recent observations of the heavens, it would add much to the value of the book so corrected, would conduce to the progress of sidereal astronomy, and would prove the ability as well as the experience of the compiler also. Nor need there be any difficulty in accepting that, in such a work as the *Cycle*, new and original in its own day, unique in character and comprehensiveness still, and aiming at describing, sometimes with exactitude, sometimes in a brief cursory manner only, nearly half the heavens, there was an

immense deal left to other men in subsequent ages, with more time at their disposal and larger telescopes, both to improve, perfect, and extend; while to have attempted merely to observe *all* the objects as fully as some of them were, during the comparatively short time the *Cycle* was in preparation, by one man in his private house, would have occupied centuries. And this necessary difference of degree of attention which my father had paid to the very different stellar objects all included together in the *Cycle*, was both abundantly explained by him and understood and appreciated by his contemporaries. So that some of them would take up the book to fish out therefrom a mere approximate note of some star-group to begin their own observations upon; while others would sit down either to study in it the long series of micrometer measures which he had made, year after year, on such an absorbing object as γ *Virginis* or to discuss his orbital representations of its movements both in the past and for the future.

"But in place of any such common-sense and simple-honesty style of criticising a special book as this, and which book no one, particularly observers, need attend to if they can get better information elsewhere, it is most astounding to find that the author of the paper just printed by the Royal Astronomical Society has made few or no observations himself, and has no pretence of being able to produce or having produced a book equally comprehensive and much more exact than the *Cycle*. He has merely collected, at the hands of two or three other persons, after the world has progressed for half a century, after the author of the *Cycle* is dead and his book no longer to be purchased, and when many new professionally appointed men are established in public Observatories in various countries, furnished with telescopes of nine times the power of that which belonged to the private author of the *Cycle*, and have brought them to bear, with plenty of time, leisure, and experience, on a few only of his less important entries, with the certain result of finding some of the old numbers improvable; the writer of the paper taken up by the Royal Astronomical Society has, I say, merely collected a very few corrections of such very correctible and weak items, and then endeavours . . . to ignore the very existence of all the completer, better, more numerous observations in the *Cycle*, and to persist in insinuating that everything whatever in that book must be of the character of the few cited errata, but which he tries to imply are of some very bad origination."

The sentiments expressed in this letter will, I am sure, recommend themselves to every honest man.

Mr. Barclay's Observatory,
Leyton, 1879. *March* 13.

On the practical Advantages of Hartnup's Method of testing Chronometers. By Arthur E. Nevins, Esq.

The difficulties attending the observation of lunar distances at sea and the errors to which the computation of Greenwich time therefrom is liable are well known to be so numerous that this method is hardly ever now practically used by officers in the merchant service, and therefore it becomes a very important matter to have all the reliable information which can be obtained about the performance of marine chronometers, as they are almost exclusively relied upon for ascertaining the longitude at sea.

Having had an experience in the management of chronometers at sea extending over several voyages, and having during that time found that the method of testing chronometers adopted by Mr. Hartnup at the Liverpool Observatory is exceedingly useful, both in selecting a chronometer for purchase and also in carrying on the time by it afterwards, I trust that some account of this experience may be useful to others.

Account of the performance of a Marine Chronometer from the time it left the maker's hands for a period of four years.

In 1874 I selected from the chronometers at Mr. Hartnup's Observatory the chronometer "George Timewell," 1656. This, like most new chronometers, was greatly gaining in its rate, my first three voyages exhibiting respectively $0^{s}.9$, $0^{s}.4$, and $0^{s}.2$ per day of acceleration.

After these voyages the instrument was tested in March, April, and May 1877, at the Liverpool, Observatory, preparatory to a voyage to Australia and India. The following Table shows the results obtained from this test:—

1877.	Mean Daily Rates. s	Mean Temperature Fahrenheit. °
March 10–17	−0·95	85
17–24	−0·05	70
24–31	−0·60	55
31–April 7	+0·65	70
April 7–14	−0·12	85
14–21	+0·33	70
21–28	−0·17	55
28–May 5	+0·78	70
May 5–12	+0·15	85
12–19	+0·80	70

The values of C and T we found to be—

$$C = -0{\cdot}0037 \qquad T = 70{\cdot}03^{s}.$$

It will be seen from the Table of Observatory Rates given above that this watch was still gaining a little on its rate, and therefore R was assumed to be +0ˢ·80, which was the rate kept during the last two weeks in which it was exposed to a temperature of 70° F., instead of +0ˢ·50, which was its value as deduced from the whole test.

A table of rates for each degree of temperature from 40° to 90° F. was then calculated, the values of C and T being taken as obtained from the whole test by the above calculation, and the value of R being taken at +0ˢ·80.

The formula used for these calculations is

$$\text{Rate in any given temperature} = R - (N^2 \times C),$$

where N is the difference of the temperature in question from T, reckoned in degrees Fahrenheit.

Throughout the voyage the rates were taken from this Table day by day according to the mean temperature of the previous twenty-four hours, and the results obtained during a fifteen months' voyage are given in the following Table:—

Date.	Errors of No. 1656 on G.M.T. By Calculation.	By Observation.	Differences.	Nature of Observations for Time.
	m s	m s	m s	
1877. June 20	+1 29·0	+1 29·0	0 00·0	Left London.
Sept. 24	+2 10·5	+2 16·2	0 5·7	Melbourne time ball.
Nov. 15	+2 35·2	+3 8·1	0 32·9	Melbourne time ball.
1878. Feb. 11	+3 6·5	+3 56·0	0 49·5	Three stars with artificial horizon.
Feb. 25	+3 10·7	+3 54·5	0 43·8	Six stars with artificial horizon.
March 13	+3 14·9	+4 3·8	0 48·9	Six stars with artificial horizon.
July 3	+3 55·4	+4 53·0	0 57·6	St. Helena time ball.
Sept. 19	+4 50·7	+5 3·5	0 12·8	⊙ and ☽ with sea horizon off Start Point.

From this Table it will be seen that up to July 3, 1878, the rate had been subject to a continual acceleration in a gaining direction, but that, from that date to the end of the voyage, the watch had gone slower than its rate. By the daily comparisons which were made throughout the voyage with the two other watches on board, it was found that a sudden change in a losing direction in the rate of this watch took place on August 4; but what the cause of this change was I have not been able to ascertain.

As soon as possible after our arrival in England, this watch was sent to the Liverpool Observatory and submitted to a five weeks' test before being put into the maker's hands to be

cleaned, and that test showed the values of C, T, and R to be as below :—

$$C = -0{\cdot}0034 \qquad T = 75{\cdot}42^{\circ}\,F \qquad R = +0{\cdot}73^{s}.$$

The maker said that when he took the watch to pieces he found that the oil had become deteriorated, but that otherwise he could not find anything to account for the change of rate which had apparently taken place.

The value of the temperature coefficients C and T remain constant for long periods.

On this occasion the maker (who is a thoroughly reliable man) was particularly requested to use every care to avoid in any way altering either the compensating weights on the balance or the timing screws, in order that the change produced by simply substituting oil in good condition for that which had become deteriorated might be ascertained from a comparison of the last test with its performance after being cleaned. As soon as it was cleaned it was again tested, and the result of a five weeks' test showed that the values of C, T, and R were as below :—

$$C = -0{\cdot}0037 \qquad T = 68{\cdot}7^{\circ}\,F \qquad R = -0{\cdot}88^{s}.$$

It will be seen from these figures that the value of C was, practically speaking, unaltered, that the change in the value of T was only slight, and that the watch went about $1^{s}{\cdot}6$ per day slower with the new oil, probably on account of its being a little fast in the short arcs, in which case it would go rather slower when the balance was vibrating through longer arcs after the watch had been cleaned.

The objection has been sometimes raised to Mr. Hartnup's method of correcting rates for change of temperature, that the values of C and T would need to be frequently redetermined. That such is not the case with a good watch when carefully cleaned and kept in good repair, but that, on the contrary, the values of these two coefficients are nearly constant, will be seen from the following Table, showing the various values of C, T, and R which have been obtained for this watch from the tests to which it has been submitted at various times at the Liverpool Observatory :—

Date of Test.		C	T $^{\circ}$	R ^{s}
August and September	1874	−0·0051	71·28 F	−0·08
April	1876	−0·0035	70·30	−1·63
March—April—May	1877	−0·0037	70·03	+0·50
October and November	1878	−0·0034	75·42	+0·73
November and December	1878	−0·0037	68·70	−0·88

From these figures it will be seen that the value of T has, except in the case of the last two tests, been between 70° and 72° F., and that for the last four tests the value of C has remained almost constant, the abnormal value of C in the first test being probably caused by the rapid acceleration which was being then developed in the rate.

The values of R have been fluctuating, as might be expected in any watch which had been cleaned two or three times in the period under discussion.

On the performance of the Chronometers on board the ship "British Sceptre" during a fifteen months' voyage.

The last voyage on which this watch was used, and to which reference has been made above, was on board the ship "British Sceptre," commanded by Captain Henry Richards. On board this ship were two other chronometers, besides No. 1656 (which we will call for convenience S, standard), and by the kindness of Captain Richards I was enabled to have free access to them, and to all the papers connected with them. He also gave me the comparisons every day throughout the voyage of each of them with S, obtained by observing the simultaneous readings of all three of them. From these comparisons the first and second differences for each pair were obtained each day and tabulated. The mean temperature experienced was also recorded.

One of these chronometers, No. 196 (which we will call A), illustrated very well the advantages to be obtained from a knowledge of the temperature corrections for the rate of even a single watch in working with a set of two or more chronometers on a long voyage.

From the above mentioned comparisons it was found that in a temperature of from 55° to 60° F. the second differences from day to day between S and A were practically $0^s{\cdot}0$, showing that in that temperature the two watches were making the same rate; while in crossing the tropics, with temperatures ranging from 80° to 82° F., the difference of the rates of the same two watches was from $4^s{\cdot}5$ to $5^s{\cdot}0$ per day, A going slower than S by this amount.

All that was known about the going of A was that the chronometer maker, who had rated it in London in the months of May and June 1877, probably in a temperature of say 65° F., more or less, had given $-1^s{\cdot}3$ per day as the rate.

With regard to S the following Table of rates had been obtained in the manner which has been described above:—

Rates of S in various Temperatures.

The rate in	55°	60°	65°	70°	75°	80°	85°	Fahrenheit
was	−0·03	+0·43	+0·71	+0·80	+0·71	+0·43	−0·03	seconds per day.

Under these circumstances it was a matter of certainty that the Greenwich Mean Time (and therefore of course the longitude) indicated by these watches would differ continually—as the temperature varied—and the following Table shows the amount of those differences, obtained on the passage from London to Melbourne:—

Table showing the relative performances of S and A, the rate of A not being corrected for change of Temperature.

Date	First Differences between S and A. By Calculation.	First Differences between S and A. By direct Comparison.	Differences of Greenwich Mean Times indicated.	Mean Temperatures Fahrenheit.
1877.	h m s	h m s	m s	°
July 1	0 18 33·6	0 18 36·5	0 2·9	75
8	0 18 47·7	0 19 2·2	0 14·5	79
15	0 19 00·1	0 19 35·2	0 35·2	81
22	0 19 11·6	0 20 9·2	0 57·6	78
29	0 19 24·4	0 20 41·2	1 16·8	72
Aug. 5	0 19 38·7	0 21 4·6	1 25·9	59
12	0 19 50·0	0 21 7·5	1 17·5	58
19	0 20 1·0	0 21 7·9	1 6·9	59
26	0 20 12·4	0 21 9·1	0 56·7	61
Sept. 2	0 20 25·2	0 21 14·1	0 48·9	56
9	0 20 35·1	0 21 13·8	0 38·7	57
16	0 20 45·1	0 21 15·4	0 29·8	58
23	0 20 56·6	0 21 19·8	0 23·2	57
24	0 20 58·1	0 21 19·8	0 21·7	

The errors of these watches on September 24, by account, and also by the Melbourne time signal, were as below:—

	S. m s		A. m s
Error by account	+2 10·6	Error by account	−18 47·5
„ observation	+2 16·2	„ observation	−19 3·6
Error of G.M.T.	0 5·6	Error of G.M.T.	0 16·1
Placing the ship to the West of the true Longitude	0° 1′ 24″	Placing the ship to the East of the true Longitude	0° 4′ 1″·5

Method adopted to ascertain the rates of A in various temperatures.

From the information which has been already given, it will be seen that if the table of rates in various temperatures for S be assumed to be correct, all the data are at hand which are necessary for ascertaining the rates made by A in the various temperatures experienced between London and Melbourne.

The method adopted to find the rate of A in any temperature was as follows:—From the tabulated comparisons of these two watches the difference of the rates made by them was ascertained on every day on which that temperature was experienced as the mean temperature of 24 hours, from the column of second differences; the known rate of S was applied to this difference, and the result gave the rate of A in that temperature.

Thus it was found that on 7 days the mean temperature had been 56°, and on 5 days 80°, and the following calculations were made to ascertain the rates of A in temperatures 56° and 80° F.

Observed Second Differences between S and A.

In temp. 56°		In temp. 80°
s		s
+0·3		−4·8
+0·4		−4·9
+0·0		−4·8
+0·1		−4·9
+0·1	In referring to these second differences,	−4·5
−0·4	+ denotes A gaining on S;	
−0·2	− „ A losing on S.	
Mean +0·04		−4·78 Mean
Rate of S in temp. 56° +0·07		+0·43 Rate of S in temp. 80°
∴ Rate of A in temp. 56° +0·11		−4·35 ∴ Rate of A in temp. 80°

By a series of calculations similar to the above, the subjoined Table was obtained of the

Rates of A in various Temperatures.

Temperature Fahrenheit.	Daily Rates of A.	Temperature Fahrenheit.	Daily Rates of A.
°	s	°	s
53	+0·43	57	+0·03
54	+0·22	58	+0·21
55	+0·37	59	−0·08
56	+0·11	60	−0·06

Temperature Fahrenheit.	Daily Rates of A.	Temperature Fahrenheit.	Daily Rates of A.
°	s	°	s
61	−0·26	74	−2·81
62	−0·20	75	−3·29
63	−0·01	76	−3·56
64	−0·43	77	−3·78
65	−0·79	78	−3·90
66	−1·06	79	−3·97
67	−1·48	80	−4·35
68	−1·61	81	−4·50
*		82	−5·03
73	−2·63	83	−5·43

From an inspection of this Table, it will be seen that the rates found in the way which has been described are not absolutely accurate; it is not to be expected that, where some certain degree of temperature has only occurred on one or two days, the rate for that temperature could be ascertained to a tenth or even half a second. Nevertheless the Table gives a very fair idea of the corrections to be applied. By using the last Table as a sort of general guide, the following Table of rates for A was drawn up for use at sea:—

In Temp.	55°	60°	65°	70°	75°	80°	85°	Fahrenheit
Rate of A =	+0·3	−0·3	−0·7	−1·9	−3·2	−4·3	−6·0	seconds per day.

Advantages obtained by correcting the rate of A for change of temperature.

The "British Sceptre" left Melbourne on November 15, 1877, bound to Madras, and on that day the errors of the two watches, S and A, were ascertained by observing the drop of the time ball, and during the passage the same rates were used for S as had been used on the previous passage, and the rates given in the last Table were used for A. From Madras we went to Coconada, and thence to Gobaulpore, at which port, on the night of February 24–25, 1878, a good set of observations for time were obtained. The relative performances of these two watches on the voyage from Melbourne to Gobaulpore is shown in the following Table:—

* 69°, 70°, 71°, and 72° did not occur as the mean temperature for any 24 hours during the passage.

Table showing the relative performances of S and A during 102 days, the rates of both being corrected for change of temperature.

Date.	Differences between S and A. By Calculation.	Differences between S and A. By Comparison.	Differences of the G. M. Times indicated.	Mean Temperatures Fahrenheit.
1877.	h m s	h m s	m s	°
Nov. 15	0 23 3·4	0 23 3·4	0 00·0	61
18	0 23 5·7	0 23 8·4	0 2·7	60
25	0 23 10·4	0 23 16·0	0 5·6	60
Dec. 2	0 23 16·0	0 23 23·0	0 7·0	66
9	0 23 28·3	0 23 36·7	0 8·4	77
16	0 23 58·1	0 24 7·6	0 9·5	82
23	0 24 35·0	0 24 43·5	0 8·5	84
30	0 25 15·2	0 25 23·6	0 8·4	82
1878.				
Jan. 6	0 25 52·8	0 26 1·4	0 8·6	83
13	0 26 31·5	0 26 37·4	0 5·9	82
20	0 27 7·9	0 27 11·4	0 3·5	81
27	0 27 41·9	0 27 46·0	0 4·1	80
Feb. 3	0 28 15·5	0 28 19·4	0 3·9	82
10	0 28 52·7	0 28 53·8	0 1·1	82
17	0 29 30·4	0 29 28·4	0 2·0	81
25	0 30 10·1	0 30 6·1	0 4·0	

On February 25, 1878, the ship being then at Gobaulpore, the time was obtained from the mean of six sets of observations of stars taken with a sextant and artificial horizon on shore, three of the stars being to the eastward and three to the westward of the meridian, with the following results:—

Errors on Greenwich Mean Time.

	Of S. h m s	Of A. h m s
By account	+0 3 44·3	0 26 25·8
By observation	+0 3 54·5	0 26 11·6
Difference	0 0 10·2	0 0 14·2
Error of longitude	0° 2′ 33″ Westerly	0° 3′ 33″ Westerly.

The rate for A given in London, as has been mentioned above, was $-1^{s}\cdot3$ per day, and that rate agreed very closely with the rate obtained in Melbourne by the time ball, and also with the mean rate made on the passage from London to Melbourne.

It would therefore have appeared more than probable, if nothing had been ascertained about its rates by the comparisons with S, that $-1^{s}\cdot3$ was a correct sea rate for this watch; if that rate had been used from Melbourne to Gobaulpore, the result would have been as below:—

	h	m	s
Feb. 25. Error of A on G.M.T. by account	−0	22	7·9
" " " observation	−0	26	11·6
(With rates *not* corrected for temperature) difference	0	4	3·7

i.e. error of longitude = 1° 0′ 55″·5 easterly.

By applying the necessary temperature corrections to its rate, this watch indicated a longitude only 3½′ in error; but by using one mean rate in the usual manner, the error accumulated on the same passage would have been over a degree.

Verification of the previously ascertained Tables of Rates for A.

The method has been already explained by which the rates made in various temperatures by A on the passage from London to Melbourne were ascertained from the second differences arising from the daily comparisons of the two watches under consideration. The same method was adopted in order to ascertain what rates A had made on the passage from Melbourne to Gobaulpore in the various temperatures experienced.

It will have been seen above that the G.M.T. deduced from S was in error to the extent of 10ˢ·2 on February 25, and as that error had been acquired in 102 days, the mean error of the rate would be 0ˢ·1, and therefore R would be +0ˢ·9, instead of +0ˢ·8. This correction was made to the rate of S before making the calculations from which the following Table was obtained of the

Rates of A *in various Temperatures.*

Temp. Fahr. °	Rates of A. s	Temp. Fahr. °	Rates of A. s
58	−0·83	72	−2·61
59	−1·30	74	−3·06
60	−0·34	76	−3·63
61	−0·58	78	−3·84
62	−0·54	79	−4·15
65	−0·89	80	−4·23
66	−1·19	81	−4·36
68	−1·71	82	−4·73
69	−1·70	83	−4·90
71	−2·00	84	−5·41

N.B. Temperatures 63°, 64°, 67°, 70°, 73°, 75°, and 77° were not experienced as the mean temperature for 24 hours during the period referred to by the above Table.

The following Table shows the rates adopted for A on the passage from Bimlipatam (the port at which we completed our cargo) to London. It will be seen that it differs but slightly from the similar Table of rates for the same watch given above as used between Melbourne and Gobaulpore (p. 332).

In Temp.	55°	60°	65°	70°	75°	80°	85°	Fahr.
Rate of A	+0·3	−0·3	−0·8	−1·8	−3·2	−4·3	−5·8	secs. per day.

There is one remark which it is necessary to make about the last two Tables which have been given. The objection may be raised, that the rate given in the last Table for 55° temperature does not correspond with what it apparently ought to be from the rates given in the Table which precedes it for temperatures 58° and 59°. The reason for that is that these two temperatures were each only experienced for two days on the passage under discussion, and the two rates were therefore rejected in favour of the rates obtained on the passage from London to Melbourne, from much more numerous observations in the same two temperatures.

On March 12, 1878, the errors of the two watches on Greenwich Mean Time were obtained by observations of 6 stars (3 east and 3 west of the meridian) taken with a sextant and artificial horizon on shore at Bimlipatam. We left that port on March 19 for London, and on the passage the rates used for A were those given in the last Table. The rates used for S were based on the corrected value for R for that watch, which has been given above, namely +0ˢ·9, instead of +0ˢ·8 as used during the two preceding passages. They may be found from the Table of rates for that watch which has been already given (p. 328) by applying +0ˢ·1 to each rate in that Table.

The next Table shows the results obtained from the two watches during the homeward passage.

Table showing the relative performances of S and A during a six months' passage, the rates of both being corrected for change of temperature.

Date. 1878.	Differences between S and A. By Calculation. h	m	s	By Comparison. h	m	s	Differences of G. M. Time indicated. m	s	Mean Temperatures Fahrenheit.
March 12	0	31	27·4	0	31	27·4	0	00·0	
									83
17	0	31	55·0	0	31	54·6	0	00·4	
									84
24	0	32	35·5	0	32	34·4	0	1·1	
									86
31	0	33	18·2	0	33	14·9	0	3·3	
									87
April 7	0	34	2·6	0	33	57·7	0	4·9	
									86
14	0	34	45·6	0	34	37·6	0	8·0	
									84

Date. 1878.		Differences between S and A. By Calculation. h	m	s	By Comparison. h	m	s	Differences of G. M. Time indicated. h	s	Mean Temperatures Fahrenheit.
April	21	0	35	26·3	0	35	17·0	0	9·3	
										86
	28	0	36	9·3	0	35	59·7	0	9·6	
										83
May	5	0	36	47·8	0	36	38·8	0	9·0	
										78
	12	0	37	19·6	0	37	10·6	0	9·0	
										73
	19	0	37	44·5	0	37	35·2	0	9·3	
										75
	26	0	38	12·0	0	38	2·6	0	9·4	
										73
June	2	0	38	36·5	0	38	27·4	0	9·1	
										71
	9	0	38	57·7	0	38	47·3	0	10·4	
										66
	16	0	39	10·3	0	38	59·4	0	10·9	
										64
	23	0	39	20·3	0	39	8·4	0	11·9	
										64
	30	0	39	31·1	0	39	19·2	0	11·9	
										70
July	7	0	39	50·5	0	39	38·5	0	12·0	
										78
	14	0	40	21·6	0	40	7·0	0	14·6	
										80
	21	0	40	55·0	0	40	34·8	0	20·2	
										81
	28	0	41	30·4	0	41	10·2	0	20·2	
										82
Aug.	4	0	42	7·6	0	41	48·6	0	19·0	
										80
	11	0	42	42·0	0	42	20·5	0	21·5	
										83
	18	0	43	20·2	0	42	49·9	0	30·3	
										82
	25	0	43	57·1	0	43	19·0	0	38·1	
										74
Sept.	1	0	44	23·8	0	43	40·4	0	43·4	
										70
	8	0	44	43·6	0	44	4·9	0	38·7	
										68
	15	0	44	59·0	0	44	26·4	0	32·6	
										66
	19	0	45	6·2	0	44	36·7	0	29·5	

Advantageous results obtained by correcting the rates of A for change of temperature.

On July 3, 1878, the errors of the watches were obtained by the St. Helena time ball, as below :—

Errors on G.M.T.

	Of S.	Of A.
	h m s	h m s
By observation	+0 4 53·0	−0 34 34·0
By account	+0 4 55·5	−0 34 43·1
∴ Errors of G.M.T.	0 0 2·5	0 0 9·1
	Placing the ship to the Eastward of correct Longitude	Placing the ship to the Westward of correct Longitude
	0° 0′ 37″·5	0° 2′ 16″·5

On September 19, 1878, the errors on Greenwich Mean Time of the chronometers were ascertained from observations of the Sun and Moon, taken with the sea horizon, Start Point being distant about 1½ mile, the Sun being to the east and the Moon to the west of the meridian; they were as follows:—

Errors on G.M.T.

	Of S.	Of A.
	h m s	h m s
By observation	+0 5 3·5	−0 39 33·2
By account	+0 5 43·0	−0 39 23·2
∴ Errors of G.M.T.	0 0 39·5	0 0 10·0
	Placing the ship to the Eastward of correct Longitude	Placing the ship to the Eastward of correct Longitude
	0° 9′ 52″·5	0° 2′ 30″

If the mean rate which has before been given for A, viz. −1ˢ·3 per day had been used on the voyage from Bimlipatam towards London, the error of the longitude on July 3 (at St. Helena) would have been 1° 10′ 51″, instead of 0° 2′ 16″·5, the error found after correcting the rates for change of temperature.

Again, by applying −1ˢ·3 as the daily rate for the rest of the passage up to September 19, the error of the longitude deduced from A would have been 2° 0′ 18″, instead of 0° 2′ 30″, its amount after correcting the rate for change of temperature.

With regard to the other watch, S, it seems unnecessary to make any further remarks.

I should only like to point out that the error of the longitude found from the mean of these two chronometers, when the rates of both had been corrected for change of temperature, would be 0° 6′ 11″·2 east (in time 0ʰ 0ᵐ 24ˢ·7), and, after a passage of over six months, this is very near perfection.

Conclusion.

In the *Monthly Notices*, vol. xxxv. (1874–75), Nos. 2 and 5, will be found two letters from me to Mr. Hartnup, giving the results obtained on a voyage from England to Calcutta and back, from two chronometers, for which the temperature corrections had been ascertained by Liverpool Observatory tests. When the results obtained on that voyage are combined with the facts which have been given in the present paper concerning the voyage in the "British Sceptre," it may be fairly said that my experience has shown, as far as it goes, that temperature corrections computed by Hartnup's formulæ are invaluable in carrying on time with chronometers at sea.

Notes on a Persian MS. of Ulugh Beigh's Catalogue of Stars belonging to the Royal Astronomical Society.

By E. B. Knobel, Esq.

The MS. which is the subject of the following notes, is a portion of a somewhat complete copy of Ulugh Beigh's Tables recently presented to the Royal Astronomical Society by Mr. Ranyard. This MS. is in Persian, and, from the date given on the last page of the Tables, it was written in the year 1255 Hegira = A.D 1839 for "Dr. James Bird."

The complete MS. is bound up in two parts. Vol. i. consists of Ulugh Beigh's "Introduction to the Catalogue and Knowledge of the Stars," and is very handsomely written and evidently by one hand throughout. Vol. ii. contains the "Samarcand Tables" and Catalogue of Stars, and shows evidence of having been written by two or three different hands.

Our knowledge of Ulugh Beigh's Catalogue of Stars is derived entirely from the translation made by Thomas Hyde and published in 1665; a second edition of this translation was published by Gregory Sharpe, in a complete collection of all Thomas Hyde's works, in 1767, and it is this copy which has been reproduced with notes by Mr. Baily in vol. xiii. of the *Memoirs of the Royal Astronomical Society*.

Hyde's translation was made from three Persian MSS., one in the Library of St. John's College, Oxford, another in the possession of Dr. Pocock, and the third in the Savilian Collection.*

A careful comparison of the Royal Astronomical Society's MS. with Hyde shows over one hundred and twenty differences in the longitudes and latitudes of stars.

A large proportion of these differences are due to errors of that particular kind which I have indicated in my notes to

* The preface to the Catalogue which Hyde gives appears to be the thirteenth Treatise in the third part of Ulugh Beigh's Tables. *See* Sédillot, *Prolegomènes des Tables Astronomiques d'Oloug Beg*, 1853.

Sédillot's translation of Aboul Hhassan's Catalogue,* namely, errors made by confounding certain Persian or Arabic characters in transcribing or translating the original MS.

In the comparison of the Royal Astronomical Society's MS. with Hyde, 26 per cent. of the discrepancies are due to confounding the Yā ي (10) with the Nūn ن (50), and 8 per cent. to mistakes between the Yā (10) and the Lām ل (30) or *vice versâ*. In Professor Schjellerup's comparison of the Copenhagen and St. Petersburg MSS. of Al-Sûfi, by far the largest number of differences he found, viz. 20 per cent., were due to precisely the same cause as in the Ulugh Beigh MSS., that is to say, confounding the Yā with the Nūn; but he notes only 2·7 per cent. of mistakes between the Yā and the Lām. It is a singular fact that, though in these MSS. of Ulugh Beigh and Al-Sûfi we have so much confusion between the Yā (10) and the Nūn (50) and the Yā (10) and the Lām (30), we do not find a single instance in them of confounding the Nūn (50) with the Lām (30).

In the large majority of cases it is difficult to say which is the more correct reading. Where the mistake of 10 for 50 takes place in the *degrees* of longitude or latitude, it is of course easy to make the correction from the description of the star; but as all these discrepancies in the Royal Astronomical Society's MS., with only three exceptions, are in the *minutes* of longitude and latitude, it is then much more difficult to know which reading to adopt. In this MS. the Yā and the Nūn, when combined with other letters, are written exactly alike, with the exception of the diacritical point being placed over the Nūn. Presumably, therefore, we should accept as more correct a redundant letter rather than one which requires less care in writing; that is to say, that a letter with a dot over it should be accepted as more correct than a similarly formed letter without a dot. It is more reasonable to suppose that the dot has been wrongly omitted than that it has been wrongly inserted. The accompanying notes show that this rule is not quite infallible.

The great probability of errors of this kind being made in transcribing or translating Oriental MSS., shows how important it is to be cautious in founding any deduction on old Arabian observations till such probable errors have been eliminated by careful examination of more than one MS.†

The MS. under discussion (a great portion of which is badly written) is useful in affording clues to explain discrepancies which have been found in investigating other Oriental MSS.

In his recently published *Researches on the Motion of the Moon*, Professor Newcomb has discussed the observations of eclipses recorded by Ibn Junis in the Hakemite Tables and

* *Mems. Roy. Ast. Soc.*, vol. xliii. p. 64.

† In the thirteenth century Chrysococca translated a Catalogue of Stars from the Persian containing an error in the *degrees* of Yā (10) for Nūn (50). This was copied by Bullialdus in his *Astronomia Philolaica*, and repeated by Delambre, in his *Histoire de l'Astronomie*, without remark.

translated by Caussin from the Leyden MS. The following of his observations are found to be irreconcilable with the computations:—

"Lunar Eclipse 929, January 27." At the beginning of this eclipse *Arcturus* was observed to be in the east at an altitude of 18°. The Greenwich mean time of observation is $8^h\ 5^m\ 32^s$, and the tabular Greenwich time of geometric phase $9^h\ 4^m\ 20^s$. Clearly, therefore, the recorded altitude of *Arcturus* is much too low; but a highly probable error in an Arabic MS. is to confound the numbers 18 يح, 33 لج, and 38 لح, and so there can be little doubt that the real observed altitude was 33° or 38°, which has been erroneously rendered 18 by transcriber or translator.

"Lunar Eclipse 980, May 2." The altitude of the Moon at the beginning of the eclipse is given as 47° 40′. Professor Newcomb remarks that there is clearly some mistake, as this quantity exceeds the Moon's meridian altitude. The computed altitude of the Moon, Mr. Neison tells me, is 40° 33′. It is most improbable that the Arabic figures 40 and 47 could ever be confounded. But in the latitude of "No. 5 *Ursi Majoris*" in the Royal Astronomical Society's MS. the number 47 is written not very unlike a 41, and a possible explanation is here afforded.

"Lunar Eclipse 983, March 1." The altitude of the Moon when the eclipse began is given as 66°. This is impossible, as it exceeds the meridian altitude.

In examining the positions of stars in the Ulugh Beigh MS., I have noted particularly that the Bā ب (2) is occasionally written so like the Waū ﻭ (6) that the two might be easily confounded. In the longitude of the star "No. 4 *Extra Figuram Librœ*" the number 22 is written like the number 26 in the longitude of "No. 5 *Scorpionis*." Again, in the longitude of "No. 14 *Capricorni*" the Waū (6) is written so that it closely resembles the Bā (2) in the longitude of "No. 2 *Extra Figuram Librœ*." Other similar cases are found in the longitudes of "No. 27 *Capricorni*" and "No. 5 *Ferœ*." In the latter the Bā (2) is quite like the Waū (6) in the longitude of "No. 3 *Coronæ Australis*."

In comparing the figures 60 to 69 as we find them written in this MS., the two which resemble each other are the 66 and 62, and from the instances given above, I think the probability of the original MS. of Ibn Junis giving 62° as the altitude, instead of 66° as translated by Caussin, amounts almost to a certainty.

Mr. Neison tells me that the computed altitude of the Moon comes out 62° 40′.

"Lunar Eclipse 986, December 18." When the eclipse was visible the Moon was observed in the west at an altitude of 24°. Ibn Junis estimated the height of the Moon at the moment of contact ("*attouchement*") to be 50° 30′. This second altitude is of

course a great deal too high. It is a rather singular fact that in the longitude of "No. 2 *Gallinæ*" in the Ulugh Beigh MS. the numbers 28 and 50 are written side by side, and in such a manner that it is almost inevitable that the number 28 would be translated 50, and hence an explanation is suggested of the discrepancy in Ibn Junis.

"Lunar Eclipse 1002, March 1." The altitude of *Arcturus* at the commencement is given as 52° in the East, and at the end as 35°. The altitude of another star, supposed to be *α Aurigæ*, at the commencement was 14° in the west. The discrepancies here are very difficult to explain. The printed Arabic of Ibn Junis, which I have before me, gives 12° as the altitude of "Al-Simak Al-Ramih" at the commencement, and 35° for "Al-Ramih" at the end, the same designation not being used for both altitudes. Though the name "Al-Simak" is applied to another star besides *Arcturus*, viz. *α Virginis*, I cannot find the name "Al-Ramih" given to any other star except *α Boötis*. Caussin suggests that the altitude of 12° at the commencement might accord for *Arcturus*, with 35° at the end of the eclipse; but this disagrees with Professor Newcomb's computations. Time has not allowed me to compute the position of "Al-Simak Al-Aezal" for the commencement of the eclipse. With regard to the star with the altitude 14°, Caussin states that the name "Al-Hadi" is not to be found in Ulugh Beigh nor in Al-Sûfi, but he found a similar name in Scaliger for *α Aurigæ*.

In searching through Al-Sûfi I find the identical word حادي, Hâdi, applied to *α Tauri*, which is there called "Hadi al-Nadjm, The Driver of the *Pleiades*." This point was evidently missed by Caussin in his examination of Al-Sûfi. The altitude of *α Tauri* in the west at 14° would not be very discordant with an altitude of 12° in the east for "Al-Simak Al-Aezal" = *α Virginis*.

M. L. A. Sédillot, in his *Mémoire sur les Instruments astronomiques des Arabes*, confines the name "Al-Hâdi" to the star *α Tauri*, and says nothing about it being given to *α Aurigæ*. I am therefore inclined to think that Scaliger's application of the name to *α Aurigæ* was in error.

"Solar Eclipse 1004, January 23." When the eclipse began to appear on the disk the Sun was observed to be in the west at an altitude of 16° 30′; his altitude at the commencement of the eclipse was estimated to be 18° 30′.

In the comparison of the Copenhagen and St. Petersburg MSS. of Al-Sûfi, Professor Schjellerup gives seven instances in those MSS. of the figure 6 being written for 7, or *vice versâ*. It seems therefore not improbable that there has been a similar error in transcribing or translating the above altitude of 16° 30′, and for this we should read 17° 30′.

In the notes which follow, the first column gives Baily's number of the star, and in the second column Ulugh Beigh's

designation is given. In the notes H means Baily's edition of Hyde.

The magnitudes given by Ulugh Beigh are really those of Al-Sûfi, and they have never been properly translated. In Hyde's edition there are many discrepancies between the printed Persian and the Latin translation. Baily gives the magnitudes in whole numbers without the thirds of a magnitude given in the original. I have endeavoured to supply this omission by giving a complete translation of the magnitudes as found in the Royal Astronomical Society's MS. with notes, comparing them with Hyde, and with Sharpe's second edition of his translation. In the original, against some stars there is placed the initial letter of the word كبير, Kabīr, signifying "large," and against others the initial of صغير, Saghīr, "small." So that ج ے = mag. 3–2 and ج ص = mag. 3–4.

Baily's No.	Ulugh Beigh's No.	Notes.
4	4 Ursi Minoris.	Long. 3ˢ 17° 43′. H. 3ˢ 17° 13′.
7	7 „ „	Lat. 75° 41′. H. 75° 9′.
9	1 Ursi Majoris.	Long. 3ˢ 14° 15′. H. 3ˢ 14° 55′.
11	3 „ „	Lat. 43° 45′. Baily says "the latitude in the first edition (Hyde's translation) is 13° 45′, which is a true translation of the Persian, but in Sharpe's edition it is altered to 43° 45′ which is the more correct value." The true translation of the Persian in the R.A.S. MS. is 43° 45′.
22	14 „ „	Lat. 37° 0′. H. 36° 0′.
23	15 „ „	Lat. 37° 0′. H. 33° 21′. The latitude of 22 has been copied again, and the proper latitude of 23 given to 24.
42	7 Ex. hanc Fig.	Lat. 20° 15′. H. 29° 15′.
71	28 Draconis.	Lat. 60° 21′. H. 65° 21′.
77	3 Cephei.	Long. 1ˢ 27° 17′. H. 0ˢ 27° 37′.
83	9 „	Long. 0ˢ 5° 55′. Baily says, "the printed copies have 5ˢ 5° 55′, which is evidently erroneous"; and he alters it to 0ˢ 5° 55′, as it is in the R.A.S. MS.
87	2 Ex. hanc Fig.	Long. 0ˢ 9° 4′. H. 0ˢ 9° 25′.
90	3 Vociferatoris.	Lat. 60° 23′. H. 60° 33′.
109	22 „	Lat. 25° 5′. H. 25° 0′. The latitude in the R.A.S. MS. is the same as in the Pocock MS. referred to by Baily.
110	1 Ex. hanc Fig.	Long. 6ˢ 36° 31′. This is a correct translation, but H. 6ˢ 16° 31′ is of course the more correct longitude. The latitude of this star is omitted.
112	2 Coronæ.	Lat. 46° 34′. H. 46° 24′.
114	4 „	Long. 7ˢ 3° 28′. H. 7ˢ 3° 40′.

Baily's No.	Ulugh Beigh's No.	Notes.
123–130	5–12 Incumbentis Genubus.	Longitudes omitted.
132–136	14–18 „	Latitudes omitted.
147	1 Ex. hanc Fig.	Long. 7ˢ 25° 13′. H. 7ˢ 24° 13′.
150	3 Shelyâk.	Long. 9ˢ 11° 55′. H. 9ˢ 11° 10′.
154	7 „	Lat. 16° 21′. H. 56° 21′.
157	10 „	Lat. 14° 36′. H. 54° 36′.
159	2 Gallinæ.	In the longitude of this star, the character representing 28° is almost identical with that used for 50° in the latitude, and the two would be inevitably confounded. The character representing 50 is not here the Arabic letter Nūn ن, but what is called by the Arabs an Indian figure.
164	7 „	Lat. 69° 42′. H. 69° 52′.
173	16 „	Lat. 64° 24′. The Kāf (20) in the latitude of this star might be easily confounded with a Lām (30).
177	1 Inthronatæ.	Lat. 43° 46′. H. 43° 45′.
194	5 Bershâush.	Lat. 31° 0′. H. 34° 0′.
203	14 „	Lat. 21° 20′. H. 20° 21′.
210	21 „	Lat. 18° 14′. H. 18° 54′.
211	22 „	Lat. 21° 18′. H. 21° 48′.
218	3 Ex. hanc Fig.	Long. 2ˢ 14° 28′. H. 1ˢ 14° 28′.
219	1 Tenentis Habenas.	Long. 2ˢ 22° 22′. H. 2ˢ 2° 22′. Baily remarks that the longitude of this star is 20° too little. In the R.A.S. MS. the longitude is given correctly.
220	2 „ „	Long. 2ˢ 21° 25′. H. 2ˢ 21° 55′.
232	1 Serpentarii.	Lat. 34° 11′. H. 35° 51′.
235	4 „	Lat. 12° 33′. H. 32° 33′.
248	17 „	Long. 8ˢ 14° 15′. H. 8ˢ 14° 55′.
252	21 „	Lat. 3° 48′. H. 3° 18′.
257	2 Ex. hanc Fig.	Long. 8ˢ 22° 17′. H. 8ˢ 22° 37′.
271	11 Serpentis.	Lat. 14° 15′. H. 16° 15′.
301	3 Delphini.	Lat. 27° 16′. H. 27° 36′.
305	7 „	Lat. 32° 54′. H. 32° 55′.
312	4 Sectionis Equi.	Lat. 24° 16′. H. 24° 36′.
319	7 Equi Majoris.	Lat. 24° 45′. H. 34° 45′.
323	11 „ „	Long. 11ˢ 18° 25′. H. 11ˢ 8° 25′.
325	13 „ „	Lat. 14° 25′. H. 14° 15′.
330	18 „ „	Long. 11ˢ 11° 22′. H. 11ˢ 11° 34′.

Baily's No.	Ulugh Beigh's No.	Notes.
334	2 Mulieris Catenatæ.	Long. 0^s 13° 55′. This is evidently the longitude of 335 copied by mistake for this star, the proper longitude, H. 0^s 15° 46′, being altogether omitted.
347	15 „ „	Lat. 27° 16′. H. 27° 36′.
361	2 Arietis.	Lat. 7° 11′. H. 7° 51′.
372	13 „	Long. 1^s 4° 15′. H. 1^s 4° 55′.
377	5 Ex. hanc Fig.	Long. 1^s 8° 15′. H. 1^s 8° 55′.
381	4 Tauri.	Long. 1^s 53° 52′. H. 1^s 13° 52′. This longitude is unmistakable, as the diacritical point is carefully put over both Nūns (50).
382	5 „	Long. 1^s 19° 15′. H. 1^s 19° 55′. Here there is no diacritical point, and the character must be translated as a Yā (10).
385	8 „	Long. 1^s 23° 24′. H. 1^s 23° 22′.
392	15 „	Lat. 2° 52′. H. 2° 54′.
395	18 „	The longitude and latitude of 18 Tauri are omitted. Stars 19–30 are numbered 18–29. The longitude of 30 is numbered correctly, but has the latitude of 31 against it. There is no latitude against the longitude of 31. No. 32 has the correct coordinates.
417	8 Ex. hanc Fig.	Long. 2^s 17° 13′. H. 2^s 17° 43′.
432	12 Gemellorum.	Long. 3^s 6° 18′. H. 3^s 6° 58′.
439	1 Ex. hanc Fig.	Long. 0^s 23° 13′. H. 2^s 23° 13′.
449	4 Cancri.	Long. 3^s 29° 34′. H. 3^s 29° 35′.
450	5 „	Long. 4^s 0° 13′. H. 4^s 0° 43′. The R.A.S. MS. has the same longitude as the Pocock MS.
453	8 „	Long. 3^s 23° 17′. H. 3^s 23° 37′.
464–485	6–27 Leonis.	Magnitudes omitted.
471	13 Leonis.	Lat. 3° 58′. H. 3° 57′.
473	15 „	Long. 4^s 28° 27′. H. 4^s 28° 37′.
484–501	8–25 „	The longitudes and latitudes of these stars should all be shifted down one line. The elements of 8 are omitted and subsequently inserted as 26.
495	2 Virginis.	Long. 6^s 16° 25′. H. 5^s 16° 25′.
499	6 „	Long. 6^s 27° 13′; Lat. 30° 14′. H. Long. 5^s 27° 7′; Lat. 1° 30′. It is difficult to explain the large error in the latitude in the R.A.S. MS. The description and the magnitude of the star agree with Hyde. The MS. is here so clearly written, it does not admit of mistake in translation.
510	17 „	Long. 0^s 17° 19′. H. 6^s 17° 19′.
511	18 „	Long. 6^s 18° 15′. H. 6^s 18° 55′.
513	20 „	Lat. 1° 9′. H. 1° 30′.

Baily's No.	Ulugh Beigh's No.	Notes.
526	1 Libræ.	Lat. 0° 42′. H. 0° 45′. It would seem that the numbers 42 and 45 in some modes of writing Persian are likely to be confounded, for Baily notes that the St. John's College MS. gives 0° 45′ as the latitude to 518, whereas the other MSS. examined by Hyde give 0° 42′. *See* also No. 833. In the R.A.S. MS. it is impossible to confound 42 and 45.
537	4 Ex. hanc Fig.	Long. 22° 25′. The Kāf (20) and Bā (2) are here written very like the Kāf (20) and Wāū (6) in the longitude of 547, and the one might be translated for the other.
543	1 Scorpionis.	Long. 7ˢ 25° 24′. H. 7ˢ 25° 22′. There is no doubt it is written 24′ in the R.A.S. MS.; but with very little less care in writing, it might be mistaken for 22.
552	10 „	Long. 7ˢ 28° 53′. H. 7ˢ 28° 13′.
559	17 „	Long. 8ˢ 17° 15′. H. 8ˢ 17° 55′.
566	3 Ex. hanc Fig.	Lat. 20° 15′. H. 4° 15′. Here the Dal (4) has been mistaken for a Kāf (20), which in the R.A.S. MS. is a probable error. For a similar error, *see* Schjellerup's *Al-Ṣūfī*, p. 203, note 3.
575	9 Sagittarii.	Lat. 12° 0′. H. 2° 0′.
577	11 „	Long. 9ˢ 8° 15′. Lat. 3° 0′. H. Long. 9ˢ 8° 55′. Lat. 2° 0′.
578	12 „	Lat. 3° 6′. H. 3° 15′.
605	8 Capricorni.	Lat. 0° 16′. H. 0° 36′.
611	14 „	Long. 10ˢ 9° 56′. H. 10ˢ 9° 16′. The Wāū (6) in this longitude is written exactly like the Bā (2) in the longitude of 535.
613	16 „	Lat. 4° 16′. H. 4° 36′. In the R.A.S. MS. it may be 16 or 36.
616	19 „	Long. 10ˢ 0° 1′. H. 10ˢ 6° 1′.
617	20 „	Long. 10ˢ 9° 15′. H. 10ˢ 9° 55′.
618	21 „	Long. 10ˢ 2° 34′. H. 10ˢ 12° 34′.
624	27 „	Long. 10ˢ 16° 31′. The Wāū (6), is here written exactly like the Bā (2) in No. 535.
632	7 Effusoris Aquæ.	Long. 10ˢ 5° 25′. H. 10ˢ 5° 22′.
633	8 „ „	Lat. 8° 41′. H. 8° 9′.
634	9 „ „	Lat. 8° 9′. H. 8° 0′.
635–640	10–15 „ „	The latitude of 635 has been written against 640, and the latitudes of 636–640 are shifted up one line.
636	11 „ „	Long. 11ˢ 1° 15′. H. 11ˢ 1° 7′.
640	15 „ „	Lat. 1° 55′. H. 1° 15′.
650	25 „ „	Long. 11ˢ 8° 18′. H. 11ˢ 8° 58′.

Baily's No.	Ulugh Beigh's No.	Notes.
657	32 Effusoris Aquæ	Lat. 14° 0′. H. 11° 0′.
658	33 „ „	Lat. 15° 30′. H. 14° 30′.
664	39 „ „	Lat. 16° 17′. H. 16° 57′.
671	1 Piscis.	Lat. 10° 54′. H. 8° 54′.
681	11 „	Long. 0ˢ 6° 15′. H. 0ˢ 6° 55′.
682	12 „	Lat. 1° 52′. H. 1° 12′.
683	13 „	Lat. 6° 0′. H. 0° 0′. Baily's note to this star is, "Although the MSS. and printed copies have the latitude 6° 0′ south, yet there can be no question, from the description of the position of this star, that it is erroneous, and that it is very near the ecliptic. I have therefore corrected it." The latitude has evidently been taken from an erroneous copy of Ptolemy, for we find the same latitude of 6° 0′ given to this star in the editions of the *Almagest* of Halma and Grynæus, and also in Al-Sûfi.
684	14 „	Lat. 1° 29′. H. 1° 39′.
685	15 „	This star is omitted from its proper order and put last, following 704.
696	26 „	Long. 0ˢ 57° 34′. H. 0ˢ 17° 34′.
702	32 „	Long. 0ˢ 20° 15′. H. 0ˢ 20° 55′.
708	4 Ex. hanc Fig.	Long. 11ˢ 25° 13′. H. 11ˢ 22° 13′.
716	8 Ceti.	Long. 0ˢ 22° 17′. H. 0ˢ 22° 37′.
719	11 „	Lat. 18° 51′. H. 28° 51′.
728	20 „	Lat. 16° 0′. H. 16° 6′.
730	22 „	Omitted in its place, but subsequently inserted between 26 and 27 *Gigantis*.
748	18 Gigantis.	Lat. 8° 54′. H. 7° 54′.
756	26 „	Long. 2ˢ 14° 32′. H. 2ˢ 14° 34′.
759	29 „	Long. 2ˢ 11° 15′. H. 2ˢ 11° 55′.
766	36 „	Omitted in this constellation, but subsequently inserted between 24 and 25 *Fluminis*. Lat. 30° 25′. H. 30° 24′.
801	33 Fluminis.	Long. 1ˢ 0° 24′. H. 1ˢ 0° 25′.
806	4 Leporis.	Long. 2ˢ 9° 47′. H. 2ˢ 9° 43′.
810	8 „	Long. 2ˢ 11° 40′. H. 2ˢ 11° 43′.
815	1 Canis Majoris.	Lat. 36° 30′. H. 39° 30′.
821	7 „ „	Lat. 41° 19′. Baily remarks, "The Persian copies have the latitude 45° 19′, which does not agree with the description of the star. Hyde's translation has 41° 19′, but I know not on what authority; yet, as it agrees better with the true position of the star, I have retained it." The R.A.S. MS. gives 41° 19′, exactly the same as Hyde, which evidently differs from the three MSS. he examined.

Baily's No.	Ulugh Beigh's No.	Notes.
832	18 Canis Majoris	Long. 3ˢ 21° 25′. Here the R.A.S. MS. agrees with H. (Sharpe's edition of Hyde), and differs from Hyde's translation, which gives 3ˢ 11° 25′.
833	1 Ex. hanc Fig.	Lat. 22° 45′. H. 22° 42′. The R.A.S. MS. agrees with that of St. John's College.
836	4 „	Long. 3ˢ 1° 8′. H. 3ˢ 1° 7′.
840	8 „	Long. 2ˢ 20° 15′. Lat. 57° 30′. H. Long. 2ˢ 20° 55′. Lat. 58° 30′.
841	9 „	Lat. 58° 30′. H. 59° 30′.
848	3 Navis.	Long. 3ˢ 18° 13′. H. 3ˢ 28° 13′.
850	5 „	Long. 3ˢ 25° 22′. H. 3ˢ 24° 22′.
865	20 „	Long. 4ˢ 9° 55′. H. 4ˢ 9° 59′.
886	41 „	Lat. 60° 15′. H. 62° 15′. Baily says "this latitude is 3° too little." It is probably copied from Al-Sûfi,* or from copies of the *Almagest* similar to those of Grynæus, Halma, and Trapezuntius. The discrepancy in the R.A.S. MS. is probably due to transcriber.
888	43 „	Long. 5ˢ 8° 31′. H. 3ˢ 8° 31′.
889	44 „	Baily says that neither of these stars was observed by Ulugh Beigh, and he does not give their longitudes and latitudes. The R.A.S. MS. gives these elements, but they are simply the longitudes and latitudes of the *Almagest* copied without alteration or reduction. The magnitudes, however, are Al-Sûfi's.
890	45 „	
908	18 Hydri.	Long. 5ˢ 12° 17′. H. 5ˢ 12° 37′. In the R.A.S. MS. it may be 17 or 37.
914	24 „	Long. 6ˢ 18° 15′. H. 6ˢ 18° 55′.
927-931	3–7 Corvi.	In the constellation *Corvus* the stars 4–7 should be numbered 3–6. No. 7 is omitted altogether, but the transcriber evidently imagined the omitted star was No. 3, the longitude and latitude of which he has inserted between 14 and 15 *Centauri*.
941	10 Centauri.	Long. 7ˢ 11° 16′. H. 7ˢ 11° 6′.
949	18 „	Lat. 34° 48′. H. 32° 48′.
956	25 „	Long. 6ˢ 21° 15′. H. 6ˢ 21° 55′.
965	34 „	Long. 6ˢ 0° 11′; Lat. 15° 20′. H. 7ˢ 0° 51′; Lat. 55° 20′.
970–979	2–11 Feræ.	The latitudes of these stars have all been shifted down one line and are not against their proper longitudes. A space then follows in the column of longitudes, after which the coordinates are correctly copied.

* *Vide* Schjellerup's *Al-Sûfi*, p. 232.

Baily's No.	Ulugh Beigh's No.	Notes.
973	5 Feræ	Long. 7ˢ 22° 37′. 22 might here be translated 26, the Bā is exactly the Waū in the longitude of 997, 3 *Coronæ Australis.*
978	10 „	Long. 7ˢ 25° 21′. H. 7ˢ 25° 41′.
987	19 „	Long. 7ˢ 16° 18′. H. 7ˢ 16° 58′.

Star Magnitudes.

Stellæ Ursi Minoris.

No.	Mag.	No.	Mag.	No.	Mag.
1	3	3	4	6	2
2	4	4	4	7	3
		5	5-4		

Extra hanc Figuram.

No.	Mag.
1	4[1]

[1] Mag. Hyde Lat. 4 Pers. 3
„ Sharpe „ 3 „ 3

Stellæ Ursi Majoris.

No.	Mag.	No.	Mag.	No.	Mag.
1	4	10	4-5	19	3-2
2	5	11	3	20	3-4
3	5	12	3-4	21	3-4
4	5	13	3-4	22	3-4
5	5	14	5-4	23	3-4
6	5	15	5-4	24	3[2]
7	4-5[1]	16	2	25	2
8	4	17	3-2	26	2
9	4	18	3-4	27	2

[1] Mag. Hyde Lat. 4-3 Pers. 4-5
[2] „ „ 3-4

Extra hanc Figuram.

No.	Mag.	No.	Mag.	No.	Mag.
1	3	4	4	6	4
2	5	5	4	7	6
	4			8	6

Stellæ Draconis.

No.	Mag.	No.	Mag.	No.	Mag.
1	5	11	4	22	5
2	4	12	4–3	23	5
3	3–2[1]	13	5–4	24	3
4	4–3[2]	14	5–4	25	3
5	5–4[3]	15	5–4	26	4
6	5	16	5–4	27	3–4
7	5	17	4	28	5–4
8	5	18	4	29	3–4
9	5[4]	19	4–3	30	3–4
10	3[5]	20	6	31	3–4
		21	6		

[1] Mag. Hyde Lat. 3 Pers. 3–4
[2] ,, ,, ,, 4 ,, 4–3
[3] ,, ,, 3–2
[4] ,, ,, Lat. 5 Pers. 5–6
[5] ,, ,, ,, 3–4 ,, 3.

Stellæ Cephei.

No.	Mag.	No.	Mag.	No.	Mag.
1	5–4	5	4	8	4–3
2	4	6	4	9	5
3	4–3	7	5	10	4
4	3			11	6

Extra hanc Figuram.

No.	Mag.	No.	Mag.
1	5–4	2	4–3

Stellæ Vociferatoris (Boötes).

No.	Mag.	No.	Mag.	No.	Mag.
1	5–4	8	4–5[2]	16	3
2	5–4	9	4–5	17	4
3	5–4	10	5–4[3]	18	4
4	5	11	5	19	4[5]
5	3	12	5[4]	20	3
6	4–3	13	5	21	4
7	4–3[1]	14	5	22	4[6]
		15	5		

[1] Mag. Hyde Lat. 4–3 Pers. 4
[2] ,, ,, ,, 4–5 ,, 4–3
[3] ,, ,, ,, 5–4 ,, 5–6
[4] ,, ,, ,, 5 ,, 5–4
[5] ,, ,, 4–3
[6] ,, ,, Pers. 9 Sharpe ,, 4

Extra hanc Figuram.

No.	Mag.
1	1

Stellæ Coronæ.

No.	Mag.	No.	Mag.	No.	Mag.
1	2	4	6	6	4
2	4	5	4	7	4
3	4[1]			8	4

[1] Mag. Hyde 4-5

Stellæ Incumbentis Genubus (Hercules).

No.	Mag.	No.	Mag.	No.	Mag.
1	3-4	10	4	20	6
2	3	11	3	21	6
3	3-4	12	4	22	6
4	4-5	13	5[3]	23	4
5	5[1]	14	5[4]	24	4
6	4[2]	15	4[5]	25	4[6]
7	4	16	5	26	4
8	4	17	4	27	4
9	4	18	4	28	5
		19	4		

[1] Mag. Hyde 3
[2] ,, ,, 5
[3] ,, ,, 5-6
[4] Mag. Hyde 5-6
[5] ,, ,, 4-3
[6] ,, ,, 4-3

Extra hanc Figuram.

No.	Mag.
1	4

Stellæ Shelyâk (Lyra).

No.	Mag.	No.	Mag.	No.	Mag.
1	1	4	4	8	4[4]
2	4-3	5	4[1]	9	3
3	4-3	6	4[2]	10	5
		7	3[3]		

[1] Mag. Hyde 4-5
[2] ,, ,, 4-5
[3] Mag. Hyde 3-4
[4] ,, ,, 4-5

Stellæ Gallinæ (*Cygnus*).

No.	Mag.	No.	Mag.	No.	Mag.
1	3[1]	7	4[4]	12	3
2	6[2]	8	4	13	4
3	5	9	4	14	4
4	6[3]	10	3	15	4
5	2	11	4[4]	16	4
6	3			17	5

[1] Mag. Hyde 3–4
[2] „ „ 6–5
[3] „ „ 3–2
[4] Mag. Hyde 4–5
[5] „ „ 4–5

Extra hanc Figuram.

No.	Mag.	No.	Mag.
1	4	2	4

Stellæ Inthronatæ (*Cassiopeia*).

No.	Mag.	No.	Mag.	No.	Mag.
1	4[1]	5	3	10	6
2	3	6	4	11	4[5]
3	4	7	4[2]	12	3
4	3[2]	8	4[4]	13	6
		9	5		

[1] Mag. Hyde 4–3
[2] „ „ 3–2
[3] „ „ 4–5
[4] Mag. Hyde 4–5
[5] „ „ 4–5

Stellæ Bershâush (*Perseus*).

No.	Mag.	No.	Mag.	No.	Mag.
1	nebulosa	10	3	18	4
2	4	11	4	19	4
3	3[1]	12	2	20	5
4	4–5	13	4–5[2]	21	5
5	5	14	omitted[3]	22	4
6	4	15	4	23	3
7	2	16	4	24	4
8	4	17	4	25	3–4
9	4			26	3–4[4]

[1] Mag. Hyde 3–4
[2] „ „ 4–5
[3] Mag. Hyde 4–5
[4] „ „ 3

Extra hanc Figuram.

No.	Mag.	No.	Mag.	No.	Mag.
1	5–6	2	5–6	3	5

Stellæ Tenentis Habenas (Auriga).

No.	Mag.	No.	Mag.	No.	Mag.
1	4	5	5	10	3[2]
2	5	6	3	11	2
3	1	7	1[1]	12	6
4	2	8	4	13	6
		9	4		

[1] Mag. Hyde 4 | [2] Mag. Hyde 3–4

Stellæ Serpentarii (Ophiuchus).

No.	Mag.	No.	Mag.	No.	Mag.
1	3–4[1]	9	5[5]	17	5
2	3[2]	10	4[6]	18	5–6
3	4[3]	11	5	19	3
4	4	12	3	20	5
5	4–3	13	4–5	21	5
6	4	14	4–5	22	5
7	3	15	4–3	23	5
8	3[4]	16	4–5	24	5

[1] Mag. Hyde 3
[2] „ „ 3–4
[3] „ „ Lat. 4 Pers. 3
„ Sharpe „ 3 „ 3
[4] „ Hyde 3–4
[5] „ „ 5–4
[6] „ „ 4–3

Extra hanc Figuram.

No.	Mag.	No.	Mag.	No.	Mag.
1	4	3	4	4	4
2	4			5	4

Stellæ Serpentis.

No.	Mag.	No.	Mag.	No.	Mag.
1	4	7	3[4]	13	4
2	4–5	8	4	14	4[5]
3	3[1]	9	3	15	4
4	3[2]	10	3–4	16	4
5	5	11	4	17	4[6]
6	4[3]	12	5	18	4

[1] Mag. Hyde 3–4
[2] „ „ 3–4
[3] „ „ 4–5
[4] Mag. Hyde 3–4
[5] „ „ 4–3
[6] „ „ 4–3

Stellæ Sagittæ.

No.	Mag.	No.	Mag.	No.	Mag.
1	4	3	5	4	5
2	6			5	5

Stellæ Aquilæ.

No.	Mag.	No.	Mag.	No.	Mag.
1	6	4	5	7	6
2	3[1]	5	3	8	6
3	2[2]	6	6	9	3

[1] Mag. Hyde 3–4
[2] Mag. Hyde 2–3

Extra hanc Figuram.

No.	Mag.	No.	Mag.	No.	Mag.
1	3[1]	3	3[2]	5	2[4]
2	3	4	4[3]	6	3[5]

[1] Mag. Hyde Lat. 3 Pers. 3–4
„ Sharpe „ 3–4 „ 3–4
[2] „ Hyde 3–4
[3] „ „ 4–5
[4] „ „ 5
[5] „ „ 3–4

Stellæ Delphini.

No.	Mag.	No.	Mag.	No.	Mag.
1	4[1]	4	3[2]	8	6
2	6	5	3[3]	9	6
3	6	6	3–4	10	6
		7	3–4		

[1] Mag. Hyde 4–5
[2] Mag. Hyde 3–4
[3] Mag. Hyde 3–4

Stellæ Sectionis Equi (*Equuleus*).

No.	Mag.	No.	Mag.	No.	Mag.
1	4	2	6	4	5–6
		3	5–6		

Stellæ Equi Majoris (*Pegasus*).

No.	Mag.	No.	Mag.	No.	Mag.
1	2–3	8	5[1]	14	5–6
2	2–3	9	4–3	15	3–4
3	2–3	10	3–2[2]	16	5–6
4	2–3	11	3–4	17	3
5	4	12	3–4[3]	18	4
6	4	13	5–6	19	4
7	3			20	4

[1] Mag. Hyde Lat. 5 Pers. 5–6
[2] ,, ,, 4–3
[3] ,, ,, 4–5

Stellæ Mulieris Catenatæ (*Andromeda*).

No.	Mag.	No.	Mag.	No.	Mag.
1	3–4	9	4–3	16	4
2	4	10	4–5	17	4–3
3	4	11	5–4	18	4–3
4	4–5	12	2–3	19	4
5	4–5	13	4	20	5
6	5–4	14	4–5	21	5–6
7	4–3	15	3	22	5–6[1]
8	4–3			23	4–3

[1] Mag. Hyde Lat. 5 Pers. 5–6

Stellæ Trianguli.

No.	Mag.	No.	Mag.	No.	Mag.
1	3	2	3	4	3[2]
		3	5–6[1]		

[1] Mag. Hyde 5 | [2] Mag. Hyde 3–4

Stellæ Arietis.

No.	Mag.	No.	Mag.	No.	Mag.
1	3–4	5	5	10	4
2	3	6	6	11	5
3	5–6	7	5	12	5
4	5–6	8	4	13	4
			4		

Extra hanc Figuram.

No.	Mag.	No.	Mag.	No.	Mag.
1	3-4[1]	3	5	4	5
2	4			5	5-6

[1] Mag. Hyde 3-2

Stellæ Tauri.

No.	Mag.	No.	Mag.	No.	Mag.
1	4	12	3-4	22	4
2	4	13	3-4	23	5
3	4-3	14	1	24	6
4	4-3	15	3-4[2]	25	5
5	6	16	5	26	5
6	3	17	5	27	5
7	4	18	5	28	5
8	4[1]	19	3	29	5
9	4	20	4	30	5
10	4	21	4	31	5
11	3-4			32	5[3]

[1] Mag. Hyde 4-3 | [2] Mag. Hyde 3 | [3] Mag. Hyde 4

Extra hanc Figuram.

No.	Mag.	No.	Mag.	No.	Mag.
1	5[1]	5	5	8	5
2	5	6	5[2]	9	5[4]
3	5	7	4[3]	10	5[5]
4	5			11	5

[1] Mag. Hyde 4 | [3] Mag. Hyde 5

[2] „ „ 6-7 | [4] „ „ 5-4

[5] Mag. Hyde. Lat. 5 Pers. 5-6

Stellæ Gemellorum.

No.	Mag.	No.	Mag.	No.	Mag.
1	2	7	4-3	13	3-4
2	2	8	5-6	14	4-3
3	4-3	9	5	15	4-3
4		10	3-4	16	3-4
5		11	3	17	3
6	4	12	4-3	18	3[1]

[1] Mag. Hyde 4

Extra hanc Figuram.

No.	Mag.	No.	Mag.	No.	Mag.
1	4-5	3	5-6	6	5-6
2	4-5	4	5-6	7	4-5
		5	5-6		

Stellæ Cancri.

No.	Mag.	No.	Mag.	No.	Mag.
1	nebulosa.	4	4	7	4
2	4-5	5	4	8	5-6
3	4-5	6	4	9	4

Extra hanc Figuram.

No.	Mag.	No.	Mag.	No.	Mag.
1	4-5	2	4-5	4	5
		3	5		

Stellæ Leonis.

No.	Mag.	No.	Mag.	No.	
1	4	4	3[2]	6 to 27	Magnitudes omitted.[3]
2	4	5	3		
3	3[1]				

[1] Mag. Hyde 3-4 | [2] Mag. Hyde 3-2

[3] Mag. Hyde:—

No.	Mag.	No.	Mag.	No.		Mag.
6	2	14	4	22		3
7	3	15	4	23		3-4
8	1	16	6	24	Lat.	4-3
9	4	17	6		Pers.	4
10	5	18	6	25		4
11	6	19	5-4	26		5
12	6	20	2	27		1
13	4-3	21	5			

Extra hanc Figuram.

No.	Mag.	No.	Mag.	No.	Mag.
1	5	4	5	6	5
2	5	5	5	7	5
3	4[1]			8	5

[1] Mag. Hyde 4-5

Stellæ Virginis.

No.	Mag.	No.	Mag.	No.	Mag.
1	5	10	3	18	5–6
2	5	11	5–6	19	5–6
3	5	12	6	20	5–6
4	5	13	3	21	5
5	3	14	1–2	22	4
6	3	15	3–4	23	4
7	3	16	5–6	24	4
8	6	17	6	25	4
9	4			26	4[1]

[1] Mag. Hyde 4–3

Extra hanc Figuram.

No.	Mag.	No.	Mag.	No.	Mag.
1	5	3	5	5	5
2	5	4	5[1]	6	6[2]

[1] Mag. Hyde 6

[2] „ „ Lat. 6 Pers. 3 Sharpe Lat. 6 Pers. 6

Stellæ Libræ.

No.	Mag.	No.	Mag.	No.	Mag.
1	3–2	4	5–6	6	5–6
2	5–6	5	4	7	4
3	3–2			8	4

Extra hanc Figuram.

No.	Mag.	No.	Mag.	No.	Mag.
1	5	4	6	7	3–4
2	4–5	5	6	8	4
3	4–5	6	4	9	4

Stellæ Scorpionis.

No.	Mag.	No.	Mag.	No.	Mag.
1	3	8	2	15	4
2	3	9	3	16	3–4
3	3	10	5–6	17	3
4	3–4	11	5–6	18	3–4
5	4	12	3	19	3
6	4	13	3	20	3
7	3[1]	14	4	21	3–4

[1] Mag. Hyde 3–4

Extra hanc Figuram.

No.	Mag.	No.	Mag.	No.	Mag.
1	4-3[1]	2	5	3	5

[1] Mag. Hyde 4-5

Stellæ Sagittarii.

No.	Mag.	No.	Mag.	No.	Mag.
1	3-4	11	4-5[4]	22	3
2	3-2[1]	12	5-6	23	4-5[8]
3	3[2]	13	4-5	24	4-5[9]
4	3	14	4[5]	25	3-4[10]
5	4	15	6-7[6]	26	4-5[11]
6	3	16	5[7]	27	4-5[12]
7	4[3]	17	6	28	5
8	nebulosa	18	5-6	29	5
9	4	19	4-5	30	5
10	4	20	5-6	31	5
		21	4-3		

[1] Mag. Hyde 3
[2] „ „ 3-2
[3] „ „ 4-3
[4] „ „ 4
[5] Mag. Hyde 4-5
[6] „ „ 6 "obscura"
[7] „ „ 5-6
[8] „ „ 4
[9] Mag. Hyde 4
[10] „ „ 3
[11] „ „ 4
[12] „ „ 4

Stellæ Capricorni.

No.	Mag.	No.	Mag.	No.	Mag.
1	3-4	10	6	20	4
2	5-6	11	4	21	4
3	3-4	12	4	22	4-5
4	6-7	13	4-5	23	3-4
5	6	14	4-5	24	3
6	6	15	5-4	25	5-6
7	6	16	6	26	5
8	6	17	6	27	5
9	6	18	5-6	28	5
		19	4		

Stellæ Effusoris Aquæ.

No.	Mag.	No.	Mag.	No.	Mag.
1	6–7	15	4–5	29	4
2	3–4	16	4	30	5
3	5	17	6	31	5
4	3–4	18	4–3[2]	32	5
5	5	19	4–5[3]	33	5
6	6	20	6	34	5
7	3–4[1]	21	5–6	35	5
8	4–3	22	5–6	36	4
9	3–4	23	4–5[4]	37	4
10	4–3	24	4–5	38	4
11	3–4	25	4–5	39	4
12	3–4	26	4–5	40	4
13	4	27	4	41	4
14	5–6	28	4	42	1

[1] Mag. Hyde 5–6 | [3] Mag. Hyde 4

[2] „ „ 3 | [4] „ „ 4

Extra hanc Figuram.

No.	Mag.	No.	Mag.	No.	Mag.
1	4–3	2	4–3	3	4–3

Stellæ Piscis.

No.	Mag.	No.	Mag.	No.	Mag.
1	4	12	4	24	5
2	4–5	13	4	25	5
3	4–5	14	5[1]	26	6–7[5]
4	4	15	4[2]	27	6–7[6]
5	4	16	4–5[3]	28	6–7[7]
6	4	17	4	29	4
7	4	18	4	30	4
8	4	19	3–4[4]	31	4
9	6	20	4	32	4
10	6	21	5–6	33	4
11	4	22	3–4	34	4
		23	5		

[1] Mag. Hyde 6 | [2] Mag. Hyde 4 | [6] Mag. Hyde 6 "minuta"

[2] „ „ 5 | [4] „ „ 3 | [7] „ „ 6 „

[3] „ „ 6 "minuta"

Extra hanc Figuram.

No.	Mag.	No.	Mag.	No.	Mag.
1	4	2	4	4	4
		3	4		

Stellæ Ceti.

No.	Mag.	No.	Mag.	No.	Mag.
1	4	8	4	16	3–4
2	3	9	4	17	6
3	3	10	4–3[1]	18	6
4	3·4	11	4–3	19	5–6
5	4	12	3–4	20	5–6[3]
6	4	13	4–5[2]	21	3–4
7	4–5	14	3–4	22	3–4[4]
		15	3–4		

[1] Mag. Hyde 4 | [2] Mag. Hyde Lat. 5 Pers. 5–6
[2] ,, ,, 4 | [4] ,, ,, 3–2

Stellæ Gigantis (Orion).

No.	Mag.	No.	Mag.	No.	Mag.
1	nebulosa	14	6	26	2
2	1	15	6	27	2
3	2	16	5	28	2
4	4[1]	17	4	29	3–4
5	4	18	4	30	4
6	6	19	4	31	3–4
7	5	20	4	32	3–4
8	5	21	4	33	4–5
9	6	22	3[2]	34	4–5
10	6	23	3[4]	35	1
11	5	24	3[5]	36	4–3
12	5[2]	25	4	37	4–3[6]
13	4			38	3–2[7]

[1] Mag. Hyde 4–5 | [5] Mag. Hyde 3–4
[2] ,, ,, 5–6 | [6] ,, ,, Lat. 4–3 Pers. 4
[3] ,, ,, 3–4 | [7] ,, ,, ,, 3 ,, 3–2
[4] ,, ,, 3–4

Stellæ Fluminis (Eridanus).

No.	Mag.	No.	Mag.	No.	Mag.
1	4	12	4[3]	24	5[11]
2	4	13	5–4[4]	25	4
3	4–5	14	3–2[5]	26	4
4	4–5	15	5–6[6]	27	4
5	4	16	4[7]	28	4[12]
6	4–5[1]	17	4[8]	29	4
7	5–6	18	4	30	4–3
8	4	19	4[9]	31	omitted[13]
9	4	20	4[10]	32	4
10	3–4	21	4	33	4
11	3–4[2]	22	4	34	1
		23	4		

[1] Mag. Hyde 4
[2] ,, ,, 4
[3] ,, ,, 3–4
[4] ,, ,, 3–4
[5] ,, ,, 4
[6] ,, ,, 5
[7] ,, ,, 4–3
[8] Mag. Hyde 5–6
[9] ,, ,, 4–5
[10] ,, ,, Lat. 4 Pers. 4–3
,, Sharpe ,, 4–3 ,, 4–3
[11] ,, Hyde 5–6
[12] ,, ,, 4–5
[13] ,, ,, 4

Stellæ Leporis.

No.	Mag.	No.	Mag.	No.	Mag.
1	5	5	4–3	9	4–3
2	5	6	4–3	10	4–3
3	5	7	3–4	11	4–3
4	5	8	3–4	12	4[1]

[1] Mag. Hyde 4–3

Stellæ Canis Majoris.

No.	Mag.	No.	Mag.	No.	Mag.
1	1	7	5	13	5
2	4[1]	8	5	14	3
3	5	9	3	15	3
4	4	10	5	16	4
5	4	11	5	17	3
6	5	12	4	18	3[2]

[1] Mag. Hyde 4–5
[2] Mag. Hyde 3–4

Extra hanc Figuram.

No.	Mag.	No.	Mag.	No.	Mag.
1	4	5	5	8	4-5
2	4	6	4-5	9	3
3	5	7	4-5	10	omitted[2]
4	4-5[1]			11	4-5

[1] Mag. Hyde 4 | [2] Mag. Hyde 3

Stellæ Canis Minoris.

No.	Mag.	No.	Mag.
1	4	2	1

Stellæ Navis.

No.	Mag.	No.	Mag.	No.	Mag.
1	5	16	4	31	2
2	3	17	2	32	3
3	4-3	18	5	33	4-3
4	5	19	5	34	6
5	5-6	20	5	35	2
6	4-3	21	5	36	4
7	4	22	4	37	3
8	4	23	4	38	3
9	5	24	4	39	3
10	4-3[1]	25	4-3	40	4
11	5-6[2]	26	4-3	41	4-5[3]
12	3	27	4	42	4
13	5	28	4	43	3-4
14	5	29	4-5	44	1
15	4	30	4-5	45	3-4[4]

[1] Mag. Hyde 4-5

[2] „ „ Lat. 5 Pers. 5-6

[3] „ „ 4-3

[4] „ „ Lat. 3 Pers. 3-4

Stellæ Hydri.

No.	Mag.	No.	Mag.	No.	Mag.
1	4-5	9	4-5	18	3
2	4	10	4-5	19	4
3	4	11	6-7	20	4-3[2]
4	5	12	2	21	4-3
5	4-3	13	4	22	4
6	6	14	4	23	3
7	1[1]	15	4-3	24	3-4
8	4-5	16	3-4	25	3-4
		17	4-5		

[1] Mag. Hyde 4 — [2] Mag. Hyde 4

Extra hanc Figuram.

No.	Mag.	No.	Mag.
1	3	2	4

Stellæ Crateræ.

No.	Mag.	No.	Mag.	No.	Mag.
1	4	3	4	6	4-5
2	4	4	5	7	4-5
		5	4-5		

Stellæ Corvi.

No.	Mag.	No.	Mag.	No.	Mag.
1	3[1]	3	5	6	3
2	3	4	3	7	omitted[2]
		5	3		

[1] Mag. Hyde 3-4 [2] Mag. Hyde 3

Stellæ Centauri.

No.	Mag.	No.	Mag.	No.	Mag.
1	5	13	4-3	26	3
2	5	14	4	27	5
3	4	15	4-3	28	5-6
4	5	16	3	29	3
5	3	17	4-3	30	omitted[1]
6	3	18	3	31	2
7	5	19	5	32	2
8	4-5	20	5	33	3-4
9	4	21	5	34	2
10	4	22	5	35	1
11	4	23	3	36	2-1
12	4-3	24	5	37	4-5
		25	5-4		

[1] "Ptolemæus dicit esse magnitudinis 3"

Stellæ Feræ (Lupus).

No.	Mag.	No.	Mag.	No.	Mag.
1	3	7	5	14	4
2	3	8	5	15	5-4[5]
3	4-3	9	4-3[1]	16	5[6]
4	3-4	10	5[2]	17	5[7]
5	4-3	11	4-5[3]	18	.6
6	5	12	4[4]	19	5-6
		13	5		

[1] Mag. Hyde 5
[2] „ „ 4-5
[3] Mag. Hyde 5
[4] „ „ 4-5
[5] „ „ 5
[6] Mag. Hyde 5-4
[7] „ „ 5-6

Stellæ Thuribuli (Ara).

No.	Mag.	No.	Mag.	No.	Mag.
1	6	3	4-3	6	4
2	4	4	5-6	7	4
		5	4-5		

Stellæ Coronæ Australis.

No.	Mag.	No.	Mag.	No.	Mag.
1	4	5	5-6	10	6
2	6	6	5	11	5-6
3	6-5	7	5	12	5-6
4	5-6	8	5	13	5
		9	6		

Stellæ Piscis Australis.

No.	Mag.	No.	Mag.	No.	Mag.
1	4	5	5	8	5
2	4	6	6-7	9	4-3[1]
3	4	7	5	10	4
4	4			11	3-4

[1] Mag. Hyde 5-4

A Formula for reducing Precession in Right Ascension and Declination from Bessel's to Struve's Constants. By Professor Dr. A. Krueger, Director of the Observatory, Gotha.

Denoting by p_o and q_o the precession of a star in R.A. and Decl. computed with the constants of Bessel, viz.:

$$m = 46''.04370, \quad n = 20''.05960 \text{ for } 1800$$
$$= 46''.07456, \quad = 20''.04990 \text{ ,, } 1900$$

and by p, q the precessions of the same star according to Struve's constants, viz.:

$$m = 46''.06230, \quad n = 20''.06070 \text{ for } 1800$$
$$= 46''.09079, \quad = 20''.05207 \text{ ,, } 1900$$

the following formula will give the reduction from Bessel to Struve:

$$p - p_o = +0^s.001072 + 0^s.000054837\, p_o \text{ for } 1800$$
$$= +0^s.000750 + 0^s.000108227\, p_o \text{ ,, } 1900$$

$$q - q_o = +0^s.000054837\, q_o \text{ for } 1800$$
$$= +0^s.000108227\, q_o \text{ ,, } 1900$$

or,

		Factor.	Diff.
1800	$p - p_o = +0^s.00107 + 0^s.0005484\, p_o$	1 : 18236	1618
1810	$+0^s.00104 + 0^s.0006018\, p_o$	1 : 16618	1354
1820	$+0^s.00101 + 0^s.0006551\, p_o$	1 : 15264	1150
1830	$+0^s.00098 + 0^s.0007085\, p_o$	1 : 14114	789
1840	$+0^s.00094 + 0^s.00007619\, p_o$	1 : 13125	860
1850	$+0^s.00091 + 0^s.00008153\, p_o$	1 : 12265	754
1860	$+0^s.00088 + 0^s.00008687\, p_o$	1 : 11511	666
1870	$+0^s.00085 + 0^s.00009221\, p_o$	1 : 10845	594
1880	$+0^s.00081 + 0^s.00009755\, p_o$	1 : 10251	532
1890	$+0^s.00078 + 0^s.00010289\, p_o$	1 : 9719	479
1900	$+0^s.00075 + 0^s.00010823\, p_o$	1 : 9240	

For $q - q_o$ the precession q_o is to be corrected by the same factor.

Example: $\alpha = 2^h\ 0^m\ 0^s$ $\delta = +88^\circ\ 0'$ for 1825; by direct computation.

	s		
p_o	$= +22{\cdot}2155$,	$q_o = +17{\cdot}3700$	Bessel
p	$= +22{\cdot}2180$,	$q = +17{\cdot}3712$	Struve.

By formula, the factor being 1 : 14656,

$$p - p_o = +0{\cdot}0010 + 0{\cdot}0025 = +0{\cdot}0035 \text{ s}$$
$$q - q_o = +0{\cdot}0012$$

Gotha, 1879, *Feb.* 10.

Les longueurs du pendule à secondes à Poulkova, à St.-Pétersbourg et aux différents points de la Russie occidentale, corrigées de l'influence produite par la flexion des supports du pendule construits par M. Repsold. Par M. A. Savitsch, Professeur d'Astronomie à l'Université de St.-Pétersbourg.*

(*Abstract.*)

The paper is a sequel to the author's Memoir presented to the Royal Astronomical Society in 1872, and printed in their *Memoirs*, vol. xxxix., pp. 19–29. By the aid of the researches of Peirce, Cellerier, and Plantamour in regard to the flexibility of the supports of the pendulums as constructed by M. Repsold, he is at present able to give the lengths of the seconds pendulum for different points of Western Russia with more precision than in his Memoir of 1872. The corrected results are:—

Station.	Latitude N.			Longitude E. of Greenwich.			Length of Seconds Pendulum in Paris lines.
	°	′	″	h	m	s	
Tornea	65	50	43	1	36	54	441·2460
Nicolaistadt	63	5	33	1	26	26	441·1228
St. Petersburg	59	56	30	2	1	14	441·0254
Revel	59	26	37	1	39	1	441·0125
Dorpat	58	22	47	1	46	54	440·9697
Jacobstadt	56	30	3	1	43	4	440·8835
Vilna	54	41	2	1	41	12	440·8288
Belin	52	2	22	1	40	52	440·7203
Krements	50	6	8	1	42	54	440·6467
Kamenetz-Podolsk	48	4	39	1	46	18	440·5778
Kischeneb	47	1	30	1	55	18	440·5212
Ismail	45	20	34	1	55	16	440·4413

* The Memoir will be printed *in extenso* in the *Memoirs* of the Society.—Ed.

The author remarks that the reversible pendulum and its tripod, constructed by M. Repsold, are very convenient for transport and differential observations of the length of the seconds pendulum in different places; but, to obtain the correct length in any particular place, recourse must be had to a series of observations difficult to execute with precision. He suggests that the pendulum should be suspended at a given place, as well from its actual tripod as from a solid support fixed in a wall, as by Captain Kater and other English observers. The comparison of the time of oscillation for these two methods of suspension would be sufficient to determine the correction depending on the flexibility of the tripod.

The Memoir is dated January 11, 1879.

On a New Method of determining Astronomical Refractions.

By David Gill, Esq.

The law of astronomical refraction is by no means known with certainty. Bessel and Nyren have, it is true, arrived at very similar results on different hypotheses, but the state of our knowledge of refraction (especially beyond 80° zenith distance) is not satisfactory.

The ordinary well-known method of determining refraction is to observe the zenith distance of stars at their upper and lower culmination. Then, with an assumed latitude of the Observatory and an assumed law of refraction, to calculate the polar distances, and finally to find such a correction to the assumed latitude and assumed law of refraction as shall reduce the sum of the squares of the residuals to a minimum. The whole question then becomes a very involved one, for it includes, besides an imperfectly known law of refraction, all the unknown errors of division of the circle, the errors of flexure, &c., which are so difficult to determine completely.

I think, therefore, that a perfectly independent method of determining the absolute refraction at any altitude, and which is entirely independent of any assumed law, is not only a great desideratum in practical astronomy, but a subject of much interest as a physical research. I therefore lay the following proposal before the Society in its present form with the hope of benefiting, in the after practical application of the method, by the suggestions of the Fellows.

To fix our ideas:

1. Let us suppose an Observatory situated on the Earth's Equator.

2. Let this Observatory be provided with an instrument on

the principle of what is now commonly known as a Talcott's Zenith Telescope, and this telescope be provided with horizontal wires, over which the vertical transit of a star may be observed.

3. At such a station suppose two stars whose declination is 0°, and whose difference of right ascension is known. If vertical transits were observed with such an instrument at exactly equal zenith distances on opposite sides of the zenith, then the arithmetical sum of the hour angles will differ from the true difference of right ascension of the stars by twice the refraction.

4. The apparent altitude would be obtained directly from the apparent hour angle and the known declination and latitude of the place; hence we have directly what we want, viz. the true refraction for an apparent altitude.

It is quite true that the case I have supposed is the most favourable possible; but at Observatories of considerable latitude the method may still be employed with every prospect of success.

It is only necessary to select stars of such declination that they are on the prime vertical about the altitude at which we desire to investigate the refraction, and so observe the refraction in right ascension.

A small error in the declination of the star or latitude would then have no sensible effect in the result.

The conditions necessary to complete success appear to be:—

(*a*) A proper selection of stars *of uniform magnitude* which shall be on the E. and W. prime vertical in convenient pairs for the investigation of refraction at each required zenith distance, and so that there shall be a short convenient interval between the observation E. and W. at the same zenith distance.

(*b*) The rigid determination of the right ascensions of all these stars by the same observero makes the observations of vertical transits.

(*c*) The use of a reversing prism in front of the eyepiece, so that all the stars may be observed to pass through the field *apparently* in the same horizontal direction; or, better still, be observed over half the wires in one direction, and over the other half of the wires in the opposite direction.

(*d*) The construction of an equal-altitude instrument, capable of preserving the mutual rigidity of its parts for 20 minutes of time.*

(*e*) The accurate determination of the declinations of the stars. This could be done very rigidly by the method of Struve by observations in the prime vertical.

(*f*) The continuation of the observations for at least a year to eliminate the possible periodic errors of the right ascensions, and the employment of an underground clock in an airtight case.

(*g*) By confining the observation to 7th mag. stars, a sufficient selection would be obtainable, and at the same time the

* I shall present a description of such an instrument at a future Meeting.

errors due to personality in right ascension depending on magnitude would be avoided.

It is to be remarked that this method is most useful for low latitudes; but that is precisely where the greatest difficulties are encountered in the other method.

It is also to be remarked that the method is *entirely* free from systematic instrumental error.

On the Change in the Errors of Hansen's Lunar Tables between 1848 *and* 1876. By W. T. Lynn, B.A. (London).

In the *Monthly Notices* for 1860, June 8 (vol. xx., p. 320), the Astronomer Royal gave a series of comparisons of places of the Moon derived from Burckhardt's and from Hansen's Lunar Tables, with places obtained from the Greenwich observations made with both the Transit Circle and the Altazimuth instruments, for the years from 1847 to 1858. The result showed, as is well known, an immense superiority during that time of Hansen's over Burckhardt's Tables; but an impression has gained ground that the former have not in more recent years represented the Moon's place nearly so well as they did at that period. I have thought it worth while to calculate for one recent year the sums of the squares of the Moon's errors deduced from comparing the *Nautical Almanac* places (derived from Hansen's Tables) with those obtained from the Greenwich observations, and to compare them with those of one of the earlier years, the results of which were furnished by the Astronomer Royal. In doing so, I have selected the year 1876 as the last of which the Greenwich observations have been published, and compared its results with those of 1848, the earliest in which Altazimuth observations were made throughout the year. These years are separated by an interval of twenty-eight years, and the sums of the squares of the errors in longitude and ecliptic north polar distance are as follows:—

1. *From Observations with the Transit Circle.*

Year.	No. of Obs.	Sums of Squares of Errors of Longitude.	Sums of Squares of Errors of E.N.P.D.
		"	"
1848	113	1132·64	810·21
1876	82	8433·37	466·88

2. *From Observations with the Altazimuth.*

Year.	No. of Obs.	Sums of Squares of Errors of Longitude.	Sums of Squares of Errors of E.N.P.D.
		"	"
1848	199	2567·76	1989·89
1876	171	17605·94	1696·33

This comparison seems to show that, whilst the error of E.N.P.D. has not altered to the extent, at any rate, of being of a different order of magnitude (that it is somewhat smaller in 1876 being probably chiefly due to the smaller number of observations of that year), the error of longitude has, on the other hand, increased so much that the sum of the squares of the errors with each instrument was in 1876 about seven times as great as it was in 1848.

To determine whether the above increase in the sums of the squares of the errors in longitude is principally due to greater fluctuations in the error on different days, or to progressive change in the mean error for different years, I have calculated the value of the mean error for the above years, and for the year midway between them, i.e. 1862,* with the following result. (It is to be remarked that the errors of Hansen's Tables for 1848 are given, with those of later years for which the *Nautical Almanac* places were from Burckhardt's, at the end of the *Greenwich Observations* for 1859. All the errors are set down in the nature of excess of tabular over observed.)

1. *From Observations with the Transit Circle.*

Year.	No. of Obs.	Mean Error in Longitude for the Year.
		s
1848	113	+0·19
1862	85	−2·83
1876	82	+9·72

2. *From Observations with the Altazimuth.*

Year.	No. of Obs.	Mean Error in Longitude for th Year.
		s
1848	199	+1·90
1862	166	−3·55
1876	171	+9·31

These numbers indicate very clearly remarkable changes in the mean error in longitude of Hansen's Tables, which, almost insignificant at the commencement of the period here referred to, or about thirty years ago, first changed its sign (still continuing small) a few years afterwards, and subsequently to that again changed its sign and increased considerably in magnitude, to which increase that of the sums of the squares of the errors mentioned above is evidently principally due.

Some years ago, Professor Newcomb published, in the *American Journal of Science and Arts* (Number for September 1870, Second Series, vol l., p. 183), a paper entitled "Considerations on the

* 1862 is the first year in which the *Nautical Almanac* used Hansen's Tables.

Apparent Inequalities of Long Period in the Mean Motion of the Moon," in which he gives (page 191) a similar comparison of the mean errors of the longitude in different years, both from the Greenwich and Washington observations, but limiting the former (which terminate in 1868, whilst the Washington extend one year further) to those made on the meridian, or with the Transit Circle. In comparing this with the results above, it will be noticed that Professor Newcomb gives his errors in the nature of excess of observed over tabular place, or of apparent correction applicable to the tables. Within their respective limits our results are mutually to a great extent confirmatory. Professor Newcomb commences his comparison with the year 1850, in which the error in longitude, both from Greenwich and Washington observations, is very small. In 1862 the mean error from both Greenwich and Washington is about $-2\frac{1}{2}''$ for excess of tabular over observed place (as always set down in the *Greenwich Observations*). In 1868, the last year for which Professor Newcomb gives the Greenwich error (derived only from the observations of the principal observers), that and the Washington error are both about $+4\frac{1}{2}''$, whilst in 1869, for which he gives the mean error derived from the Washington observations only (those made at Greenwich being not accessible to him at the time of the publication of his paper), that error amounts to $5\frac{1}{2}''$. In 1876, as we have seen, the mean error deduced from the Greenwich observations was approaching 10", equivalent to two-thirds of a second of time.

I have had the curiosity to compute the mean error in longitude of Burckhardt's Tables for 1848. The Transit Circle observations, 113 in number, give $+7''{\cdot}87$; the Altazimuth, 199 in number, give $+8''{\cdot}68$. The sums of the squares are furnished in the Astronomer Royal's paper before referred to; they are, for the Transit Circle, 7662·82, and for the Altazimuth 18880·81. Hansen's Tables therefore do not appear to represent the Moon's place better in 1876 than Burckhardt's in 1848. The latter, it will be remembered, were published in 1812; and the author mentions in the preface that their superiority over those of Bürg (published in 1806) had been shown, in that a comparison of 167 observations made at Greenwich and Paris with places from his own Tables gave the sum of the squares of the errors in longitude only about two-thirds of that obtained from a similar comparison with places from Bürg's Tables, besides diminishing the sum of the squares of the errors in latitude.

Note on η Draconis. By W. T. Lynn, B.A. (London).

The *Nautical Almanac* star *η Draconis* appears in the Pulkowa *Catalogue de 514 Etoiles doubles et multiples* (published in 1843) as a double star, the components of which, at the distance of 4″, are stated to be of the 2·3 and 8th magnitude respectively.

The large star is contained (repeatedly observed) in all the great Greenwich Catalogues. A single observation of the small star is given in the First Seven-Year Catalogue for 1860 and the Second Seven-Year Catalogue for 1864. But in the first of those catalogues the small star appears to precede the large star by 0ˢ·37, and in the second to follow it by 0ˢ·32. Reference, however, to the original observation in the former (which observation was made on 1856, February 16) convinces me that a misunderstanding of its language was fallen into when the observations of that year were compared and reduced, and that the observation printed as referring to the large star really referred to the small one, and *vice versâ*. For the observer, Mr. Criswick, states that the small star was observed in transit over the five last wires and the large star over all the nine wires. Now the star observed over all the wires certainly precedes the other, but (apparently because the R.A., when reduced, of the second star, agrees better than that of the first with the other observations of the large star in that year) it was considered, when the results were put together at the end of the year, that the second star was the large *Nautical Almanac* star, and the star preceding it was the small companion star (which Struve, as above mentioned, calls of the 8th magnitude).

If then we transfer these observations accordingly, we shall find that the R.A. of the large star, from nine Greenwich Transit-Circle observations, is $16^h\ 22^m\ 2^s{\cdot}98$; that of the small star, from only one observation, $16^h\ 22^m\ 3^s{\cdot}17$; distance in R.A., 0ˢ·19. No N.P.D. of the small star was observed that year.

Combining this result with the other observations of the *Nautical Almanac* star in the First Seven-Year Catalogue, we shall find the R.A. in this Catalogue, for the epoch 1860, to be $16^h\ 22^m\ 6^s{\cdot}21$, instead of $16^h\ 21^m\ 6^s{\cdot}23$, as there printed. The R.A. of the small star will be $16^h\ 22^m\ 6^s{\cdot}36$, instead of $16^h\ 22^m\ 5^s{\cdot}86$. A further reduction in the R.A. of the *Nautical Almanac* star must be made, in consequence of the fact that an erroneous proper motion was used in determining its place in that Catalogue. The R.A. was not observed by Bradley, and the proper motion in the B.A.C. (used in the *Nautical Almanac* until 1873) was determined by a comparison of Piazzi's with later observations. This proper motion amounts to +0ˢ·023; but being found to be too large, the *Nautical Almanac*, in 1874 and subsequent years, used +0ˢ·005, determined by Mädler. Mr. Downing, in the *Monthly Notices* for last March, made a re-determination, and found it to be +0ˢ·004. The *Greenwich Observations* alone would give even

less than that; and it seems at any rate clear that the proper motion in R.A. is practically insensible. The First Seven-Year Catalogue being reduced to the epoch of the last year (1860), of which the observations are included in it, makes the amount of proper motion used in the reductions of some importance. Assuming that for this star to be insensible, instead of $+0^s.023$ per year as actually used, we shall have the R.A. $0^s.05$ smaller; so that finally the R.A. of η^2 *Draconis* in that Catalogue should be $16^h\ 22^m\ 6^s.16$. It is to be presumed that the *Nautical Almanac*, in calling the star η^2 *Draconis*, considered Groombridge 2345, which precedes it by about 10^s and is of $11'$ less N.P.D., to be η^1 *Draconis*.

It will be seen that the small star, in the Second Seven-Year Catalogue (where it is numbered 1869), follows the *Nautical Almanac* star by $0^s.32$.

I may mention that my attention was directed to this star by a remark of Professor Bredichin in the fifth volume of the *Annales* of the Observatory of Moscow, that the *Nautical Almanac* R.A. of it, some years ago, was more than $0^s.3$ in error. I here give the comparison between the R.A. in the successive Greenwich great Catalogues and the *Nautical Almanac* R.A. for the same epochs, correcting that of the First Seven-Year Catalogue as above:—

Catalogue.	Epoch.	R.A. in Greenwich Cat.	R.A. in *N.A.*	Error of *N.A.*
		h m s	h m s	s
Twelve-Year Cat.	1840	16 21 50·23	16 21 50·09	−0·14
Ditto do.	1845	16 21 54·19	16 21 54·32	+0·13
Six-Year Cat.	1850	16 21 58·14	16 21 58·42	+0·28
First Seven-Year Cat.	1860	16 22 6·16	16 22 6·62	+0·46
Second Seven-Year Cat.	1864	16 22 9·25	16 22 9·91	+0·66
Nine-Year Cat.	1872	16 22 15·66	16 22 16·11	+0·45

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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Lord LINDSAY, M.P., F.R.S., President, in the Chair.

The Rev. Abraham Smith, Collegiate School, Huddersfield; and

Lewis Swift, Esq., Rochester, New York, U.S.;

were balloted for and duly elected Fellows of the Society.

The President addressed the Meeting:—

"I deeply regret having to announce to the Society the news of the death of Mons. Edmond de Chazal, of St. Antoine, Mauritius. In bringing before your notice the decease of a gentleman who was not a Fellow of the Society, I may be, strictly speaking, out of order; but I feel sure that I shall be pardoned by the Society for recording publicly our feelings. I do not wish to speak of Mons. de Chazal as a personal friend for whom I held the highest esteem, but rather as a citizen of the world, who, mindful of the difficulties found in discussing the observations of the transits of *Venus* last century, owing to the uncertainty of the exact localities of the observers, placed in the hands of Her Majesty's Government a deed conveying to it the site of the Observatory I raised in the island.

"The interest he took in my work was only equalled by his tender kindness during my illness."

Extract from a Letter from Professor Asaph Hall to the Astronomer Royal.

I am glad to see, in the *Monthly Notices* of December 1878, your Note on the mass of *Mars*. Although the volume containing your paper has stood within a few feet of me for several years, I missed it in looking up the authorities on this question. The recent Note of Mr. Dunkin on the Tables of *Saturn* by Le Verrier

is interesting. My observations of the satellites of this planet are not yet discussed, but they indicate that Bessel's value of the mass of *Saturn* is nearly correct. I think that Le Verrier made some error in the perturbations of *Jupiter* and *Saturn*, by which he got some of his coefficients too large, and then, in adjusting his theory to fit the observations, he was led to diminish the mass of *Saturn*. Mr. G. W. Hill is at work on the complicated theory of *Jupiter* and *Saturn*, and in the course of two or three years we may expect his results.

In the theory of *Hyperion* I think that I have got hold of an interesting motion of the line of apsides; the observations of this satellite hitherto made are so clustered about the elongations that the elements remain somewhat uncertain, but after two years I shall be able to follow all around the planet this faint object.

Naval Observatory, Washington,
1879, *February* 18.

An apparently New Variable Star. By J. L. E. Dreyer, Esq.

On March 8, when observing the red star Schj. 109 (Lal. 16770 = Weisse I, $8^h.625$ = Schj. 3122), I remarked a very conspicuous star of the 9·0 mag. *n.p.* it, which is not in the *Durchmusterung* nor in Bond's *Zones* 46 and 47, while it occurs in zone 48 as a * 11 mag. As the Harvard *Zones* contain stars down to the 12–13 mag. (except in very crowded places, of which this is not one) or on Argelander's scale to about the 11th mag., the star *n.p.* the red one appears to be variable. It is $16^s.7$ *p.* and $103''.0$ *n.* of Schj. 109, its position being for 1855

h	m	s	°	′
8	23	56·3	+0	20·3.

The only place where I have found this star mentioned, besides Harvard Zone 48, is the Munich Catalogue of Stars, between +3° and −3° Decl., where it is stated to be of the 10th mag., and the star *s.f.* of the 9th. The latter is of the 8·5 mag. in the *Durchmusterung*.

The Observatory, Dunsink,
April 1879.

Observations of Absorbing Vapours upon the Sun.
By Professor E. Leopold Trouvelot.

In a letter published in vol. xxxiii., page 63, of the *Monthly Notices of the Royal Astronomical Society*, November 1872, Mr. Chacornac gives an account of an interesting observation of his, entitled, "On a Volcanic Appearance in the Sun." Although I do not fully understand what Mr. Chacornac means

by "Une flamme cratériforme représentant un orifice volcanique en ignition," yet, as one of my observations seems to have some relation with his own, there may be a certain interest in recording it.

As I was observing the Sun with the spectroscope at the Harvard College Observatory on the morning of July 28, 1872, at $9^h\ 0^m$, and sweeping its surface with the narrow slit of the instrument, my attention was attracted by a large black spot crossing obliquely the C line, and projecting on each side upon the spectrum. By conveniently adjusting the spectroscope, it was very easy to recognise its position, form, and size. It was situated on the southern hemisphere of the Sun, in the vicinity of a very large sunspot which was on its second return, and then not far from the east limb. This remarkable object, which very nearly formed a straight line, was very narrow and slender; but much wider towards its southern extremity, from whence it gradually decreased as it advanced northward, until it terminated on this side in a very acute extremity. From its southern end to about half its length it projected upon the spectrum on both sides of the C line, to a distance equal to about three or four times the width of this line. Its length was considerable. It began at a small distance to the south-west of the large sunspot, and thence, inclining to the west, it advanced northwards towards the centre of the Sun, in the vicinity of which it terminated; the angle it subtended being equal at least to one-sixth of the diameter of the Sun.

As soon as this observation was completed, the same part of the Sun was observed telescopically with different power eyepieces, and scrutinised with attention; but, to my surprise, I could not see the least trace of a spot or mark indicating the cause of the phenomenon so prominent on the C line. Even no difference was noticed in the granulations covering that part of the Sun from whence the absorption proceeded. However, the phenomenon had not disappeared during the time I had removed the spectroscope, as this instrument, having been replaced, continued to show the black spot sharply defined on the spectrum.

On July 29, at $9^h\ 0^m$, the slit of the spectroscope was again directed in the vicinity of the large southern sunspot, and soon the dark absorbing spot seen the day before was found in nearly the same place. However, its size was reduced, it was not so black and sharp, and it no longer projected on the spectrum, its absorbing quality having evidently diminished. This part of the Sun being also examined with the telescope, nothing unusual was noticed.

However, Mr. Chacornac had observed the Sun on the same day, at $9^h\ 0^m$ A.M., or, if we take into account the difference of longitude, about $5^h\ 30^m$ before I observed it in Cambridge; and then, according to his expressions, he saw, "Une flamme cratériforme représentant un orifice volcanique en ignition. . . . d'une

teinte bleuâtre nettement décidée . . . et soustendant un angle d'environ un septième du diamétre solaire."

As the French astronomer saw this "flamme" with the telescope $18^h\ 30^m$ after my first observation, and $5^h\ 30^m$ before the second, it might be inferred that the phenomenon had increased, and was in a particular state of visibility at the moment of his observations, since I could not, with the telescope alone, see the least traces of it before or after his observations. It seems difficult to admit that Mr. Chacornac and I have been observing a different phenomenon, since the position of this object, so near the large sunspot, could not be mistaken; and besides, by its unusual size, it is not very likely that another of such length should have formed in the same vicinity in a few hours.

For the explanation of this curious phenomenon it does not seem necessary to call forth something analogous to Ulloa's hole, as Mr. Chacornac has done, since it seems rather more simple to think that it was due to some hydrogenated vapours strongly absorbing the rays of the Sun, and which had been expelled from the interior of the large sunspot in the vicinity, as some of my observations indicate, and as will be shown presently.

May 16, 1872. The Sun having been examined with the spectroscope, several black spots, darker than the C line, made their appearance on this line, and projected on the spectrum towards the side of less refrangibility. These objects issued from an area of the Sun enclosed between a group of sunspots then very near the western limb.

July 17, 1872. A very dark spot was seen crossing the C line; no trace of it was seen on D^3 or on any other part of the spectrum.

April 16, 1873, $9^h\ 0^m$ A.M. A strong dark spot was observed on the C line; it issued from a part of the Sun situated between two groups of sunspots not very far from the western limb. By slowly moving the slit the complicated form of this object showed itself as it passed over it. It was very irregular, curved, with wider and darker places, which sometimes projected upon the spectrum, either on one or both sides of the C line. Its length was considerable, as it occupied almost the whole space between the two groups of sunspots, which were quite distant. When observed with the telescope, no traces of it were found.

September 22, 1873, $9^h\ 25^m$ A.M. A very curious group of four small dark spots, disposed in a lozenge shape, were seen projecting on the spectrum on the red side of the C line, and at some distance from it. The furthest of these spots was upon the fine line 690 of Kirchhoff's maps. These spots appeared entirely disconnected from the C line, and perfectly independent of each other. They were in rapid motion, and were seen gradually moving together towards the C line, which they reached in less than five minutes; while at the same time they diminished gradually in size and in depth of tint until they vanished.

September 28, 1873. A similar phenomenon was observed in the south-east of two large groups of sunspots.

October 29, 1873. A sunspot was crossing the western limb, when it was observed that the spectrum of the chromosphere above it was vacant and replaced by a dark spot projecting outside of the C line.

November 5, 1873, $10^h\ 30^m$. While observing the surface of the Sun between two sunspots situated at some distance from the west limb, a large black spot appeared upon the C line and projected on each side upon the spectrum, but to a greater distance on the violet side, where it extended five or six times the width of this line. Its form was that of the letter C. This part of the Sun being examined with the telescope, a bluish kind of a spot, much diffused in outlines, was seen where the spot on the C line appeared. At $2^h\ 0^m$ P.M. the spot of absorption was no more to be seen, but in its very place a small group of three sunspots had formed since the observation made in the morning.

November 6, 1873, $10^h\ 30^m$. A spot of absorption issuing from the vicinity of the small group of sunspots formed the day before was observed on the C line. With the telescope faint bluish spots could be seen on this part of the Sun. This spot of absorption, so prominent upon the C line, was not visible on the D lines, or on any other seen in the field of view. This spot was quite large, but narrow and branching off in several places. While sweeping along it with the slit, at one point near its eastern extremity the black spot, then projecting towards the red end, passed suddenly on the violet side of the C line, where it extended much further than it did on the other side. The following day it was found that where the absorbing vapour had been observed a long row of small sunspots had formed in its place, which united the two large spots by a dozen or more smaller ones.

December 24, 1873. Four small elongated dark spots, almost united end to end, were seen projected on the spectrum near the C line, on the side of greater refrangibility, where they occupied about three-fourths the width of the spectrum. They formed almost a straight line, which was a little inclined to the C line, its nearest extremity being separated from it by an interval about twice the width of this line, while the furthest was four or five times this distance. These spots were not in apparent communication with the C line.

May 30, 1874. A sunspot was passing the west limb; a spot of absorption was observed above it on the C line in place of the brilliant spectrum of the chromosphere. A similar phenomenon to that observed on October 29, 1873.

August 26, 1874, $9^h\ 15^m$. While I was observing a moderate sized sunspot with the telescope, a small bluish cloudlike form was seen issuing from this spot, and, taking a westerly course, it moved rapidly away, while at the same time it dilated considerably, until, becoming more and more diffused, it gradually became invisible.

June 1, 1875. On the morning of that day I observed with the telescope a very large elongated bluish spot, having diffused edges, in the north-east of a group of sunspots then very active and in process of formation, and which became so conspicuous the following day.

December 12, 1875, $12^h\ 30^m$. While observing a sunspot under a brilliant facula, a long trail of bluish vapours issued from the northern corner of this spot, and had its direction north-east.

September 4, 1877. Several spots of absorption were observed on the C line, in the vicinity of a group of sunspots then in great activity; the C line being reversed in many places by brilliant faculæ. One of the spots of absorption was quite extended, and, by moving the slit along it, it projected sometimes on one side of the C line, sometimes on the other, or on both. The group of sunspots close to the place where these absorbing vapours were issuing was very active; and at $1^h\ 30^m$ a sunspot, which at $9^h\ 0^m$ appeared as a veiled spot, had made its appearance. The following day, at $9^h\ 0^m$, several spots of absorption intermingled with brilliant faculæ reversing the C line were observed in the same place where they had been seen on the 4th. One of these spots was quite large and prominent, and close to the sunspot formed the afternoon before.

March 15, 1878. Quite a large spot of absorption was observed on the C line, and projected on each side upon the spectrum. This spot was issuing from the vicinity of a group of spots, being between it and a veiled spot situated about the centre of the Sun. This absorbing spot was visible on no other line in the spectrum except the C line.

May 26, 1878. In the vicinity of a large and important group of sunspots, situated in the east of the Sun, the C line was partially reversed in several places, and many dark absorbing spots were seen projecting on both sides of this line.

May 27, 1878. A very interesting phenomenon was observed on the preceding sunspot of the large group, where the spots of absorption were observed the day before. The phenomenon was the more remarkable because the spot on which it took place could be easily compared with the following one of the group, at a small distance from it. The umbra of the preceding sunspot was invaded by a bluish or purplish kind of a fog, which totally obscured its contour, and rendered the interior of the penumbra very diffused and indistinct. The phenomenon was so characteristic that I at first thought the focussing was bad, and tried to readjust it; but it was soon found that such was not the case, as the umbra of the following spot was admirably well defined, while the foggy appearance remained the same on the preceding spot. The spectrum of this spot was much darker than that of the following, and the C line was much more swollen on it than on the other. The phenomenon continued about the same for several days, and it was only on June 1 that both umbræ and their spectra

appeared the same; this change corresponded to a decrease of size of the preceding spot. On May 28 the C line was reversed on several places in the vicinity of this spot, and several dark absorbing spots were seen projected on both sides of the C line.

It is seen from these observations that on several occasions the dark spots seen on and about the C line preceded by a few hours or even days the opening of sunspots, as if they were, like the faculæ, the precursors of solar spots. The fact that these dark spectral spots were observed in every case in the vicinity of solar spots in full activity, or upon the very umbræ of such spots, is sufficient, it seems, to prove that absorbing vapours, just as well as intensely luminous gases, are ejected from the interior of the Sun through the opening of the solar spots, even if the direct observations had not shown these vapours issuing from the spots and moving away from them on the surface of the Sun.

Cambridge, U.S., January 12, 1879.

Ephemeris for Physical Observations of Jupiter, 1879. By A. Marth, Esq.

G.M.T.	Angle of Position of ♃'s Axis.	Longitude of ♃'s Meridian directed to the Earth.	Diff.	Latitude of Earth above ♃'s Equator.	Latitude of Sun above ♃'s Equator.	Annual Parallax.	Equat. Diam.	Greatest Phase.	Corr. of Long.
1879.	°	°		°	°	°	″	″	°
May 20	335·63	145·66		+1·12	+0·71	−11·43	38·30	0·380	+0·57
			4352·80						
25	335·56	178·46		1·16	0·73	11·57	38·89	·396	·58
			2·86						
30	335·49	211·32		1·20	0·75	11·65	39·50	·407	·59
			2·93						
June 4	335·44	244·25		+1·24	+0·78	−11·67	40·13	·415	+0·59
			4353·00						
9	335·39	277·25		1·28	0·80	11·61	40·78	·417	·59
			3·07						
14	335·36	310·32		1·32	0·82	11·48	41·45	·415	·57
			3·14						
19	335·33	343·46		1·35	0·85	11·28	42·13	·406	·55
			3·21						
24	335·31	16·67		1·38	0·87	10·99	42·81	·393	·53
			3·27						
29	335·30	49·94		1·41	0·89	10·63	43·50	·373	·49
			3·34						
July 4	335·30	83·28		+1·43	+0·92	−10·19	44·18	·348	+0·45
			4353·41						
9	335·31	116·69		1·46	0·94	9·66	44·85	·311	·40
			3·47						
14	335·32	150·16		1·48	0·96	9·06	45·50	·284	·36
			3·53						
19	335·34	183·69		1·49	0·98	8·37	46·13	·246	·31
			3·58						
24	335·38	217·27		1·50	1·01	7·61	46·72	·206	·25
			3·63						
29	335·42	250·90		1·51	1·03	6·78	47·26	·165	·20
			3·66						

h G.M.T.		Angle of Position of 4's Axis.	Longitude of 4's Meridian directed to the Earth.	Diff.	Latitude of Earth above 4's Equator.	Latitude of Sun above 4's Equator.	Annual Parallax.	Equat. Diam.	Greatest Phase.	Corr. of Long.
1879.		°	°		°	°	°	″	″	°
Aug.	3	335·47	284·56		+1·51	+1·05	−5·88	47·75	·126	+0·15
				4353·69						
	8	335·53	318·25		1·51	1·07	4·92	48·17	·089	·11
				3·71						
	13	335·59	351·96		1·51	1·10	3·91	48·53	·056	·07
				3·72						
	18	335·67	25·68		1·50	1·12	2·86	48·80	·030	·04
				3·71						
	23	335·75	59·39		1·49	1·14	1·78	48·99	·012	+·01
				3·69						
	28	335·83	93·08		1·47	1·16	−0·68	49·09	·002	·00
				3·66						
Sept.	2	335·92	126·74		+1·45	+1·19	+0·43	49·10	·001	·00
				4353·62						
	7	336·01	160·36		1·43	1·21	1·54	49·02	·009	−·01
				3·57						
	12	336·11	193·93		1·41	1·23	2·63	48·84	·026	·03
				3·50						
	17	336·20	227·43		1·39	1·25	3·69	48·58	·050	·06
				3·43						
	22	336·29	260·86		1·36	1·28	4·71	48·24	·081	·10
				3·34						
	27	336·37	294·20		1·33	1·30	5·68	47·82	·117	·14
				3·25						
Oct.	2	336·44	327·45		+1·31	+1·32	+6·59	47·34	·155	−0·19
				4353·15						
	7	336·51	0·60		1·28	1·34	7·43	46·80	·196	·24
				3·05						
	12	336·56	33·65		1·26	1·36	8·20	46·21	·236	·29
				2·95						
	17	336·61	66·60		1·24	1·38	8·89	45·58	·274	·34
				2·84						
	22	336·64	99·44		1·22	1·41	9·50	44·92	·308	·39
				2·74						
	27	336·65	132·18		1·20	1·43	10·03	44·25	·338	·44
				2·63						
Nov.	1	336·65	164·81		+1·18	+1·45	+10·47	43·56	·363	−0·48
				4352·54						
	6	336·63	197·35		1·17	1·47	10·82	42·86	·382	·51
				2·45						
	11	336·60	229·80		1·16	1·49	11·10	42·17	·394	·54
				2·35						
	16	336·56	262·15		1·16	1·51	11·29	41·48	·401	·55
				2·26						
	21	336·50	294·41		1·15	1·53	11·40	40·81	·403	·57
				2·19						
	26	336·43	326·60		1·15	1·55	11·43	40·15	·398	·57
				2·11						
Dec.	1	336·36	358·71		+1·15	+1·58	+11·39	39·51	·389	−0·56
				4352·05						
	6	336·27	30·76		1·16	1·60	11·28	38·90	·376	·55
				1·98						

0h G.M.T.	Angle of Position of ♃'s Axis.	Longitude of ♃'s Meridian directed to the Earth.	Diff.	Latitude of Earth above ♃'s Equator.	Latitude of Sun above ♃'s Equator.	Annual Parallax.	Equat. Diam.	Greatest Phase.	Corr. of Long.
1879.	°	°		°	°	°	″	″	°
Dec. 11	336·17	62·74		1·17	1·62	11·10	38·31	·358	·54
			1·92						
16	336·07	94·66		1·18	1·64	10·86	37·75	·339	·51
			1·88						
21	335·96	126·54		1·20	1·66	10·56	37·22	·315	·49
			1·83						
26	335·85	158·37		1·22	1·68	10·21	36·72	·291	·45
			1·80						
31	335·74	190·17		1·24	1·70	9·80	36·25	·264	·42
			4351·76						
1880.									
Jan. 5	335·63	221·93		+1·26	+1·72	+9·35	35·81	0·238	−0·38

Assumed daily rate of rotation 870°·60. The "annual parallax" is the difference of the Jovicentric longitudes of the Sun and the Earth, reckoned in the plane of *Jupiter's* equator. The last column gives the correction which is to be applied to the "longitude of ♃'s meridian directed to the Earth," in order that it may refer to the meridian which bisects the illuminated disk.

The inclinations γ and the ascending nodes Γ of the orbits of the four satellites in reference to the plane of *Jupiter's* equator are the following, the nodes being reckoned from the descending node of the equator on the planet's orbit, or from the vernal equinox of *Jupiter's* northern hemisphere:—

	Sat. I.		Sat. II.		Sat. III.		Sat. IV.	
	γ_1	Γ_1	γ_2	Γ_2	γ_3	Γ_3	γ_4	Γ_4
1879.	°	°	°	°	°	°	°	°
Feb. 19	0·0097	17·3	0·4597	25·27	0·1908	268·20	0·3246	329·61
April 20	·0097	14·8	·4605	23·25	·1902	267·77	·3249	329·54
June 19	·0098	12·5	·4614	21·23	·1896	267·38	·3253	329·49
Aug. 18	·0099	10·1	·4624	19·21	·1890	267·00	·3257	329·45
Oct. 17	·0100	7·9	·4634	17·20	·1883	266·64	·3262	329·44
Dec. 26	0·0102	5·7	0·4644	15·19	0·1876	266·30	0·3267	329·46

On the Desirability of photographing Saturn and Mars at the next Conjunction. By A. A. Common, Esq.

In the December 1878 Number of the *Notices* of this Society the particulars of the conjunction of *Saturn* and *Mars* on June 30, 1879, are given by the Astronomer Royal.

I trust that those astronomers who can will take advantage of this excellent opportunity of testing the relative actinic intensity of light of the two planets.

As they can then be taken under the same conditions, and if differently prepared plates are used—that is the ordinary wet plate and iodised collodion, and those dry plates that are more

sensitive to the red rays—the different effects of the colours of the planets might be made apparent.

Perfection of image would not be of so much importance as the effect in producing chemical action on the plate.

To show the possibility of doing this, I beg to lay before the Society two photographic plates, one with a row of pictures of *Jupiter* (showing the effect of a slight difference in the exposure on the image both as to size and density), and the other a picture of *Saturn*, all taken with an exposure of about $2\frac{1}{2}$ seconds in the case of *Saturn*, and still less in the case of *Jupiter*, by an eighteen-inch silver-on-glass Newtonian telescope.

March 1879.

Note on Large Telescopes, with suggestions for mounting Reflectors.
By A. A. Common, Esq.

The question how an increase of telescopic power may be best attained is well worth discussing, and I propose to offer some suggestions how an advance on our present means may be most readily made.

The question turns on the relative capacity of the refracting and reflecting telescope to give this increase,* and without attempting to decide which kind will eventually be found best, it is possible, I think, to show that practically the advantage is on the side of the reflector.

Although up to a certain size (taking 26 inches as the largest yet made) the refractor equals or surpasses the reflector in light-grasping power, and has certain advantages in use, as, for instance, the permanence of adjustment, readiness at all times for work, and freedom from great atmospheric disturbance, and, for its disadvantages, great length and chromatic aberration which prevents its complete use in photographic and spectroscopic work; while the reflector has, for its advantages, shorter focal length and total absence of chromatic aberration, and, for its disadvantages, want of permanency of adjustment, greater atmospheric disturbance, and a reflecting surface that requires constant attention and frequent renewal; these advantages and disadvantages do not much affect the question, for it is not on these grounds that it can be decided.

For at this point (viz. a 26-inch refractor or the equivalent sized reflector) the difficulties in producing the two kinds, or, in

* Since this paper was drafted and the conditions laid down, I have received from the author, Mr. Howard Grubb, a copy of his paper "On the Great Telescopes of the Future," published in the *Scientific Transactions* of the Royal Dublin Society, a paper I read with much interest, though I do not agree with him on several points. In it this question is most fully discussed; and although the writer does not advocate any particular kind, there is a very decided leaning to the reflector of speculum metal, the reflecting power of which he hopes to be able to improve.

other words, the cost—for that really represents the various difficulties expressed in terms of pounds, shillings, and pence—is greatly in favour of the reflector; and at that size, or a little above, the production of the refractor may for the present be said to stop, owing to the great difficulty (almost impossibility) of producing the disks of glass of sufficient purity for the purpose of the optician, and of working and supporting the object glass when made; and although these difficulties might by great care and skill be in a manner overcome, there remains the important fact that, owing to the absorption of the light by the glass, which is necessarily thicker as the aperture of the object glass increases, a point is soon reached when the hitherto greater light-grasping power of the refractor is equalled by the reflector, and beyond which it rapidly falls behind the latter, so that it is possible to conceive an object glass so large that it would let but a small fraction of the incident light through. This is of course well known, but it does not seem to have had that effect on the minds of astronomers that we would expect. It certainly does decide it beyond any doubt as far as present conditions hold. We are therefore obliged to turn to the reflector for the purpose in view; and the point then arises, which of the two surfaces—speculum metal or silver—is best for the purpose?

Sir John Herschel, in his book on the *Telescope*, gives for a Newtonian reflector with the mirrors of Lord Rosse's metal, 0·436 as the fraction of incidental light reflected; while, for the like telescope with mirrors of solid silver, he gives 0·824; and, allowing that speculum metal might be improved in reflecting power, and that the surface of silver deposited by chemical action may be less reflective than solid silver, a very large margin is left in favour of the silver-on-glass; and, considering that the mirror of speculum metal has the figure endangered if not destroyed every time it is repolished, while that once given to a glass mirror is permanent, and that there is not any difficulty, as I shall presently show, in producing this surface of silver, no choice is left as to which is best. As to any difficulty in producing glass disks—not necessarily by the glass manufacturer—for the purpose, there would not be more in any case than that met with in producing disks of speculum metal, while the weight would be in favour of the glass.*

* Mr. Howard Grubb, in the paper already referred to, has dismissed the claims of the silvered glass mirror, in a rather summary manner, in these words:—

"As regards silver-on-glass mirrors, it is hardly worth discussing their relative powers of permanence, as at the present date the art of glass-making has not arrived at that degree of perfection that will permit makers to undertake disks of any kind of suitable glass of six feet diameter; but I may mention that this is perhaps not to be much regretted, as the difficulty of preserving a silvered surface of large size would almost amount to an impossibility, and the process of silvering when the mirror is of large dimensions becomes most formidable; and, finally, it is possible that all the advantages of the silvered glass mirrors, without their corresponding disadvantages, may be secured by

The principle of mounting, whether Gregorian, Cassegranian, Herschelian, or Newtonian, is, and must be, a matter of taste. When we consider that the Melbourne reflector (the great instance of the Cassegranian principle) has—using, we presume, the large mirror only—produced photographs showing—as some of them do—such detail as the small craters between *Stadius* and *Copernicus*, and as a Cassegranian telescope failed to show the outer satellite of *Mars* at the last opposition, while it was readily seen in England with an 18-inch Newtonian under less favourable conditions, we must come to the conclusion that the principle or its adaptation is somewhere at fault.

But the simplicity of the Newtonian, and the ease with which the adjustments are made, and the favourable position given to the observer, are enough, in my opinion, to make it preferable; although, if very large sizes were attempted, it might be necessary to use the Herschelian principle, or a modification of it, if any great difficulty were found in the making of the flat mirror.

Having, then, by this process of selection got the silver-on-glass reflector on the Newtonian principle, it becomes necessary to consider the mounting; and here we come to what may be regarded as the vital point; for on the proper mounting of the reflector, so as to point it to any object in the heavens, and follow that object in its diurnal motion, while retaining all the conditions that are favourable to the best performance of the optical part, a great deal depends. As far as I know, no endeavour has been made to really find out these favourable conditions and make the mounting suit them, except in a partial manner.

I have endeavoured to find them out, and propose to indicate how they ought to be attained. They are as follows:—

1. No tube properly so called.

2. No mass of metal either below or at the side of the line joining the large and small mirrors.

3. An equatoreal mounting capable of direction to any part of the visible heavens, and of continued observation past the meridian without reversal.

4. An efficient means of supporting the mirror without flexure.

5. Driving clock. Circles to find or identify an object and motions taken to eye end.

6. A collimator for the ready adjustment of the mirrors.

other means—a matter which I shall speak more of further on"; the other means alluded to being a metal of superior reflecting power. Afterwards, in this paper, he admits that the difficulties in the case of the glass disk might be overcome, as it has been in case of the metal, without the aid of the specialist.

And here I might mention that, if it is a fact that the refractor at 35 inches aperture is equalled by the reflector of speculum metal of that size, it is hardly necessary to speak of disks of optical glass of 40 inches diameter, which when made would not nearly equal the reflector, unless we find some great—at present unknown—advantage in the refractor.

7. Such a construction of mounting as to give the greatest amount of steadiness with the least amount of friction.

8. An effectual means of resilvering the mirrors and of protecting them from dew.

9. A safe, steady, and easily adjusted platform for the observer, allowing about two hours' continuous observation without the necessity of any motion, except that from the observer's place, and of ready access.

10. A suitable locality for the erection of the telescope.

The first condition, that there shall be no tube, as such, is met by the use of a light, open, braced framing, by preference square, and which, by the use of steel tubes and rods, could be made of the required rigidity with extreme lightness. The second condition, that there shall not be any mass of metal between the large and small mirrors, is, like the first, aimed at the reduction of the atmospheric disturbance. To point out what is meant, we may take, as an example of what under these conditions would be considered the worst possible way to mount a reflector, that shown on page 134 of Newcomb's *Popular Astronomy*; and, as an approach to the best, that of the Melbourne reflector, supposing the mirror at that part where the diagonal bracing begins, and above the declination axis. The third condition indicates as the position of the mirror some point symmetrically above the polar axis, as in the mounting of Mr. Lassell's 4-foot telescope; but with this difference, that the polar axis would not be forked, but come directly under that part of the mounting bearing the mirror, and be sufficiently prolonged above the upper bearing or neck to allow a forked counterpoise to the framework necessary to carry the small mirror. The fourth condition has been so well met in the Melbourne telescope in the case of a heavy metal speculum, that it could not fail to do with glass; though something more simple might possibly be found to answer with this material in large sizes, as it has been found to answer perfectly with 18 inches. The plan suggested is this: the three primary levers bear at their extremities, instead of the secondary and tertiary systems, six flat plates, so made as to present for a bearing a broad ring, and so large as to form a circle of rings or plates almost touching and each coming under the mirror; so that, if it is conceived to be divided into six triangles by radial lines at equal distances, a ring would be under each, almost touching the straight sides; while for edge suspension three flat metal bands are connected to three equidistant points about one-twelfth of the diameter from the edge of the mirror, and each band going two-thirds of the way round the mirror.

The fifth and sixth conditions offer no difficulty. The seventh condition as regards stability is easily met, and as regards the friction, particularly as to the movement in right ascension, there is a way, by the use of the floating power of mercury, to so take off the weight from the bearing by making the polar axis of cast iron, hollow and cylindrical, and of sufficient length and

[illegible]

[illegible]

[illegible]

$$\frac{\gamma}{a} = 1-e+\frac{M^2}{2}\frac{e}{(1-e)^2}-\frac{M^4}{24}\frac{e+3e^2}{(1-e)^5}+\frac{M^6}{720}\frac{e+24e^2+45e^3}{(1-e)^8}$$
$$-\frac{M^8}{40320}\frac{e+97e^2+947e^3+1755e^4}{(1-e)^{11}}\cdots$$

$$\frac{\varepsilon}{a\sin i} = (1-e)\sin(\pi-\phi)+\frac{M}{1}\sqrt{\frac{1+e}{1-e}}\cos(\pi-\phi)-\frac{M^3}{2}\frac{\sin(\pi-\phi)}{(1-e)^3}$$
$$-\frac{M^5}{6}\sqrt{\frac{1+e}{1-e}}\frac{\cos(\pi-\phi)}{(1-e)^3}+\cdots$$

a, i, π, ϕ étant le demi-grand axe, l'inclinaison, et les longitudes du périhélie et du nœud.

Les symboles (m_1, x_1, y_1, z_1), (m_2, x_2, y_2, z_2) sont les masses et les coordonnées des planètes troublées et troublantes au temps t. J'ai trouvé qu'au temps T, après le temps t, on peut exprimer par une série la correction à faire aux coordonnées *elliptiques* x_1, y_1, z_1, pour avoir les coordonnées dans l'orbite troublée. Le coefficient de T^4 dans cette série, sauf un facteur connu de l'ordre m_2, est (pour la correction de x_1) :—

$$\frac{x_1}{r_1^3\rho_{12}^3}-\frac{x_2}{r_2^3\rho_{12}^3}-\frac{(m_1+m_2)(x_2-x_1)}{\rho_{12}^6}+\frac{(1+m_2)x_2}{r_2^6}+\frac{m_1x_1}{r_1^3r_2^3}+\frac{m_1(x_2-x_1)}{r_1^3\rho_{12}^3}$$
$$-\frac{6(x'_2-x'_1)\rho'_{12}}{\rho_{12}^4}+\frac{15(x_2-x_1)\rho'^2_{12}}{\rho_{12}^5}+\frac{6x'_2r'_2}{r_2^4}-\frac{12x_2r'^2_2}{r_2^5}$$

$$-\frac{3(x_2-x_1)^2}{\rho_{12}^5}\left\{\frac{x_1}{r_1^3}-\frac{x_2}{r_2^3}-\frac{(m_1+m_2)(x_2-x_1)}{\rho_{12}^3}\right\}-\frac{3(x_2-x_1)(x'_2-x'_1)^2}{\rho_{12}^5}$$

$$-\frac{(x_2-x_1)(y_2-y_1)}{\rho_{12}^5}\left\{\frac{y_1}{r_1^3}-\frac{y_2}{r_2^3}-\frac{(m_1+m_2)(y_2-y_1)}{\rho_{12}^3}\right\}-\frac{3(x_2-x_1)(y'_2-y'_1)^2}{\rho_{12}^5}$$

$$-\frac{3(x_2-x_1)(z_2-z_1)}{\rho_{12}^5}\left\{\frac{z_1}{r_1^3}-\frac{z_2}{r_2^3}-\frac{(m_1+m_2)(z_2-z_1)}{\rho_{12}^3}\right\}-\frac{3(x_2-x_1)(z'_2-z'_1)^2}{\rho_{12}^5}$$

$$-\frac{3x_2^2}{r_2^5}\left\{\frac{m_1(x_2-x_1)}{\rho_{12}^3}+\frac{(1+m_2)x_2}{r_2^3}+\frac{m_1x_1}{r_1^3}\right\}+\frac{3x_2}{r_2^5}(x'^2_2+y'^2_2+z'^2_2-r'^2_2)$$

$$-\frac{3x_2y_2}{r_2^5}\left\{\frac{m_1(y_2-y_1)}{\rho_{12}^3}+\frac{(1+m_2)y_2}{r_2^3}+\frac{m_1y_1}{r_1^3}\right\}-\frac{3x_2z_2}{r_2^5}\left\{\frac{m_1(z_2-z_1)}{\rho_{12}^3}+\frac{(1+m_2)z_2}{r_2^3}+\frac{m_1z_1}{r_1^3}\right\}.$$

Les symboles x', y', z' sont les derivées premières par rapport au temps ; ρ_{12} est la distance mutuelle des masses m_1 et m_2.

Naples, 11 *mars* 1879.

On the Probable Presence of Oxygen in the Solar Chromosphere.

By Arthur Schuster, Ph.D.

When Dr. Henry Draper's Paper "On the Presence of Oxygen in the Sun" appeared I was engaged in an investigation of some lines of oxygen which appear only at a temperature lower than that which gives the ordinary spectrum of oxygen. As I considered it likely that if oxygen was present in the Sun, it would show dark lines corresponding to one of its spectra, though it might show bright lines corresponding to another, Dr. Draper's researches induced me to see whether the lower temperature spectrum of oxygen, which I called the compound line spectrum, was reversed in the Sun. I have given evidence in *Nature*, vol. xvii., p. 148, that this indeed is the case. All four lines of the compound spectrum seem to be reversed in the Sun. I considered it also probable, for obvious reasons, that oxygen would reach up to a comparatively high level in the solar chromosphere, and would make itself conspicuous in that layer which commonly passes under the name of the chromospheric layer. I looked for the lines in Professor Young's list, but could not find them. A few weeks ago, however, I found that, owing to some accident, I had only referred to the preliminary Catalogue. Professor Young's final Catalogue contains indeed the two most striking out of the four lines of the spectrum in question. Their wavelengths are 5329·1 and 5435·6. Besides these two lines the spectrum contains a red line and a blue line. These lines, lying in a less luminous part of the spectrum, are easily missed. Yet the red line is strong and very characteristic. I should have expected that it would make its appearance together with the green lines. Its absence has induced me to insert the word "probable" into the title of this Note. I do not, however, believe that this absence is fatal to the explanation which I have offered of the two other lines; for not only does Professor Young include these lines in his list, but he gives them the same relative intensity which they have in the spectrum of oxygen. Professor Young's list includes 65 lines between D and E. Of these about 46 have been identified with certainty. There are therefore only about 19 left for identification, and two out of these 19 are coincident with lines of oxygen.

ERRATUM.

p. 365, line 4, read:—

$$p - p_0 = +0{\cdot}0010 + 0{\cdot}0015 = +0{\cdot}0025.$$

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXIX. *May* 9, 1879. No. 7.

Lord LINDSAY, M.P., F.R.S., President, in the Chair.

Captain Edward Barnes, The Lawn, Belper;
The Rev. William Conybeare Bruce, M.A., St. Nicholas' Rectory, Glamorganshire;
George Thorn Gwilliam, Esq., 35 Lansdowne Crescent, W.;
John Penn Hartree, Esq., M.A., M.B., Strandtown, Belfast;
Charles Augustus Jenkins, Esq., University Observatory, Oxford; and
William Edward Plummer, Esq., University Observatory, Oxford;

were balloted for and duly elected Fellows of the Society.

Extract from the Minutes of the Council, May 9, 1879.

"Since the publication of the *Monthly Notices* of the Society for January 1879 the attention of the Council has been recalled to an article headed 'Notes on the late Admiral Smyth's "Cycle of Celestial Objects &c.," by Herbert Sadler, Esq.,' containing remarks on several of the star measures given in that Catalogue, and also containing a sentence reflecting on the 'Reference Catalogue of Multiple and Double Stars,' forming vol. xl. of the *Memoirs*.

"The Council, feeling themselves responsible for the contents of the Society's publications, cannot but express their regret that they should have authorised the printing of this article in its present form.

"While they desire to uphold to the utmost perfect freedom in the criticism of scientific works, they would at the same time enforce a general rule to exclude from the Society's publications any imputation upon the personal honour or good faith of the authors; and they are sorry to observe in Mr. Sadler's article some remarks which are capable of being, and to the knowledge of the Council have been, construed in a sense which infringes this rule.

"The Council are, moreover, of opinion that Mr. Sadler was not justified in passing a sweeping condemnation on the Reference Catalogue, which is irrelevant to the rest of the article, and is entirely unsupported by the citation of the instances on which his judgment was founded.'

It was resolved that these resolutions be read at the Meeting of the Society, and printed in the next Number of the *Monthly Notices*.

Note on Sir John Herschel's Reference Catalogue of Double Stars. By Professor Pritchard, F.R.S.

Those astronomers who are seriously engaged, or otherwise interested, in the computation of the orbits of double stars, or are engaged in furnishing data for such investigations, are informed and requested to bear in mind that Sir John Herschel's references to the Catalogues of the two Struves apply solely to the Catalogues as originally published by those most eminent astronomers, and are independent of the corrections which they subsequently found it necessary to make to their original printed observations.

To working astronomers it may perhaps be unnecessary to add that they will find the corrigenda on consulting *Positiones Mediæ*, page xcii., or the *Recueil des Mémoires présentés à l'Académie des Sciences par les Astronomes de Poulkova etc.*, t. I., St.-Pétersbourg, 1853.

Order of Publication of successive Volumes of the Poulkova Observations. By M. Otto Struve.

(*Extract from a Letter to A. M. W. Downing.*)

In reply to your letter, I beg leave to inform you that vol. viii. of the *Observations de Poulkova* is not yet published. According to a resolution formerly taken, vol. viii. is designed for the Catalogue to be deduced from the meridian observations inserted in vols. vi. and vii. This Catalogue, though the reductions are considerably advanced, is not yet finished; and its publication has been considerably delayed by the lamented death of Dr. von Asten, to whom the work had been entrusted. For these reasons it can hardly be expected that vol. viii. will be published and distributed before 1881. In a similar way vol. x. of the *Observations* is designed to contain the continuation of my micrometrical measures of double stars, but as yet I have hardly been able to begin the reduction of these measures. Therefore vol. x. will not appear for a couple of years; whilst vol. xi., containing the continuation of our fundamental determinations

with the transit instrument, is nearly ready, and will be distributed very shortly.

Similar inquiries to yours have been addressed to me from different quarters. To prevent further misunderstanding, I would feel very much obliged if you would insert in the *Monthly Notices* this account of the reasons why vols. viii. and x. of the *Observations de Poulkova* will be published considerably later than respectively vols. ix. and xi.

Pulkowa, 1879, *March* 24.

The Nautical Almanac for 1882.

The Superintendent communicates the following errata, which, as referring to the Transit of *Venus*, are of unusual importance:—

'Presentation copies of the *Nautical Almanac* for 1882 to public Observatories, Institutions, and a few others, require the following corrections:

Page 402 *for* contact at Ingress 129° *read* 145°
„ contact at Egress 79° „ 114°

'The remainder of the impression has been corrected.'

Stellar Magnitudes; a Request to Astronomers.

By Edward C. Pickering, Director of the Harvard College Observatory.

The scales adopted by different observers in their estimates of stellar magnitudes differ considerably from each other, as is well known. As regards the brighter stars, these differences, indeed, are comparatively unimportant; but they become larger and more perplexing when the objects observed are faint. Variations of three or four magnitudes may be expected between the estimates made of the brightness of minute companions seen near a brilliant star. It is needless to point out the inconvenience of this state of affairs, which at times nearly deprives the estimated magnitudes found in Catalogues of their meaning, and consequently of their value.

In the hope of providing a partial remedy for this defect, a series of Photometric Observations of Stars of various magnitudes, situated near the North Pole, has been undertaken at the Harvard College Observatory. The region has been selected as one which may always be conveniently observed in the northern hemisphere, so that the brightness of a star observed in another part of the sky can readily be compared by estimate with any standard polar stars the relative brightness of which may have been determined by photometric measurements.

The table and chart given below are designed to serve as guides in finding the stars which are, as has been said, in course of photometric measurement at the Harvard College Observatory. The stars given in the table are arranged approximately in the order of their brightness, the first being *α Ursæ Minoris*, which is taken in all cases as the standard of comparison, and the next three, *ô Ursæ Minoris*, 51 *Cephei*, and λ *Ursæ Minoris*.

DM.		α 1880.		δ 1880.	
°		h	m	°	′
88	8	1	14	88	40
86	269	18	11	86	37
87	51	6	44	87	14
88	112	19	44	88	57
88	4	0	51	88	23
88	9	2	3	88	36
89	3	2	28	89	36
89	35	17	50	89	48
89	37	19	28	89	54
89	1	0	19	89	45
89	26	13	23	89	49

The chart is a copy of a sketch showing the approximate relative position of ten faint stars very near the pole, which are denoted by the italic letters *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *k*, *l*. The places of the pole for 1855, 1880, and 1900, and of five stars from the *Durchmusterung*, four of which occur in the table, are also

indicated upon the chart, to facilitate the identification of the faint stars. The objects called *c* and *e* are nearly in the prolongation of the line through DM. 89° 37 and *b*. Between these last, and more nearly in the same line than it appears to be in the chart, lies the star *a*.

The value and interest of the photometric results to be obtained at the Harvard College Observatory may be greatly increased by the co-operation of astronomers elsewhere. All who are desirous of improving the present system of comparing the brightness of stars are therefore requested to make estimates of the magnitude of as many as may be convenient of the stars above mentioned. It is desirable that the estimate should be made, for each star which may be observed, on five different nights, and that each estimate should be, if possible, entirely independent of those previously made. It will add to the value of the work if, on every occasion when the fainter stars are looked for, a record is made of such of them as can then be seen, even if no estimate of their magnitudes is attempted.

Observers are also requested to note the approximate places of any stars not represented upon the chart, but within five minutes of the place of the pole at any time between 1880 and 1900. The boundary of this region is represented on the chart by a dotted line. The stars not shown within it have been omitted as unnecessary for the purpose of finding the others, and several of these omitted stars are inconveniently faint for photometric observation; but records of their visibility at any time and place will be valuable as evidence of the state of the atmosphere and character of the instrument employed in the observations.

All astronomers who may be induced by this request to make any observations of the kind just described will confer a favour upon the Harvard College Observatory by sending to it a copy of their records, accompanied by a statement of any modification of the proposed method of observation which they may have adopted, as well as any additional details which may appear desirable, with regard to the instruments employed, &c. Unless the contrary is requested, the results will be published with the photometric measurements obtained at the Harvard College Observatory; and a copy of the publication will be sent to each observer who has co-operated in the work.

It is hoped that a large number of those astronomers whose experience has been sufficient to establish a definite scale for their estimates of stellar magnitude will consent to take part in the proposed observations, in order that the published series of observations may be complete enough to be of general utility.

On the Determination of the Solar Parallax from the Parallactic Inequalities in the Longitude of the Moon, and on the Correction to Hansen's Coefficient of the Annual Equation.

By E. Neison, Esq.

It has long been well known that if it were possible to determine from observations the true value of the coefficient of the parallactic inequality in the longitude of the Moon, it would furnish a most advantageous method of ascertaining the distance of the Sun with great accuracy. For the coefficient of the parallactic inequality is equal to the solar parallax multiplied by nearly fifteen, so that an error of 0″·15 or a little less than one-sixth of a second of arc in the value of the parallactic inequality would produce an error of only 0″·01 in the value of the solar parallax. A number of attempts have been made to ascertain the real value of the parallactic inequality in the longitude of the Moon, by comparing the observed place of the Moon with the place assigned to it by the tables, and, from the difference between observation and theory, deducing by known methods a correction to the value of the parallactic inequality employed in the tables. In this way various values have been obtained for the coefficient of the parallactic inequality, ranging between 123″·5 deduced by Burckhardt, and 126″·46, the last result deduced by Hansen. These correspond to values of the solar parallax of 8″·63 to 8″·90.

The tables with which the observations were compared were up to 1862 unsatisfactory, which rendered the determination of the corrections to the tabular values far less certain than was desirable, unless a very long series of similar observations could be obtained. Since that period Hansen's Tables have been generally employed, and being much more complete and accurate than any previous tables, it much facilitates the comparison of observation and theory and the deduction of corrections to the values of the inequalities employed in the tables.

From the latest investigation it would appear that the value of the parallactic inequality employed by Hansen in his tables is 2″·0 too great, and ought to be reduced to 124″·46, corresponding to a solar parallax of 8″·67. Unfortunately, this apparent correction is not really the true correction to the coefficient of the parallactic inequality, but is really the sum of the true correction to the coefficient of the parallactic inequality *plus* a periodical variation in the apparent semi-diameter of the Moon, due to varying contrast between the brightness of the Moon's limb and the brightness of the sky it is seen against. When the parallactic inequality tends to decrease the longitude of the Moon, then this variation in the semi-diameter tends to increase it; whilst, when the parallactic inequality increases the longitude, then the variation in semi-diameter decreases it. Accordingly, the observed value of the parallactic inequality is always less than the truth.

These drawbacks have now been known for some time, and they have been considered by most competent judges as a fatal obstacle to this method of determining the solar parallax. In this view I by no means concur, on the double ground that, not only are there theoretical objections to the sufficiency of the methods which have hitherto been used to deduce the value of this inequality from observation, but that there are more advantageous methods of accurately determining this inequality than by transits of the Moon's limb. One of these methods is about to be undertaken by Professor Winnecke, and, I am convinced, will lead to the determination of the coefficient of the parallactic inequality to within $0''.1$.

My present purpose, however, is not the consideration of the best methods of obviating these objections to the determination of the solar parallax from the parallactic inequality, but to suggest a method of obtaining the desired result without making use of this inequality, but by employing another which is not liable to the systematic errors peculiar to the parallactic inequality. This term is the term of long period, whose argument is the angular distance between the Sun and the perigee of the Moon's orbit. In my notation it is

$$\theta - a,$$

where θ is the angular distance between the mean longitudes of the Sun and Moon, and a denotes the Moon's mean anomaly. It is what Delaunay denotes by

$$D - l.$$

This term has a period of nearly 400 days, and, being a term of long period, is independent of any errors which may be contained in any of the innumerable terms of short period in Hansen's Tables. It is likewise entirely independent of the uncertainty as to the true value of the Moon's semi-diameter, or of any variations in this semi-diameter. Since Hansen's Tables were introduced, the argument of this term has undergone about thirteen revolutions, and the lunar perigee has nearly completed two revolutions, so that it ought to be possible to determine with some accuracy the value of the coefficient of this term from the fifteen years' observation of the Moon which are now available. It ought to be possible to determine the value of this term to within $0''.05$, and before long, when the theory of the terms of long period in the Moon's motion is more satisfactorily known, and when a few more years' observation are at my disposal, I think the value of this inequality could be determined from observation to within $0''.02$.

The exceptional freedom of these classes of terms of long period from systematic errors of observation, and their complete independence of the effect of the errors in the terms of short period forming the very great majority of the perturbations of the

Moon, render it very easy to determine their value from observation with very small error indeed.

In this term of long period the solar parallax is multiplied by the factor 2·118; it is therefore less favourable than the 14·25 of the well-known parallactic inequality. If, however, the value of this term could be determined by observation to within 0″·05, as I surmise, it would give the value of the solar parallax to 0″·023, whereas at present it is uncertain to five times this quantity, and may be anything between 8″·740 and 8″·915.

With the view of determining the solar parallax in this manner, I have deduced the value of this term of long period from the fifteen years' observations with the Greenwich Transit Circle between 1862 and 1876. I should have liked to have had eighteen years' continuous observations, so as to include two complete revolutions of the perigee of the Moon's orbit, and when I can obtain the observations for the years 1877–1879 I shall repeat the work, including these years, so as to obtain a perfectly symmetrical investigation.

During this period rather over 1,500 observations of the Moon were made with the Greenwich Transit Circle, but a number of these had to be rejected as having been made under faulty conditions, as indicated by the notes appended to them. There remained 1,464 good observations which form the basis of the present investigation.

Let

Q sin q = the term of long period with the argument $(\theta - a)$,

W sin w = the term of long period with the argument $(2\theta - 2a)$,

M sin μ = the annual equation, μ being the mean anomaly of the Sun;

and put δQ, δW, δM for the corrections required by Hansen's tabular coefficients of these terms, these coefficients being Q, W, M.

Further, put

δl = the correction required by Hansen's value of the Moon's mean longitude,

$\delta\epsilon$ = the correction to Hansen's value of the Moon's mean longitude at the mean epoch of the observations.

Then Δ, the error in the Moon's tabular longitude, was equated to the above corrections in the form

$$\delta Q \sin q + \delta W \sin w + \delta M \sin \mu + \delta l + \delta\epsilon = \Delta.$$

The observations of each lunation were grouped together to facilitate the work, forming a system of 186 sets of equations of the above form.

The great difficulty in comparing Hansen's Tables with the Greenwich observations consists in the remarkable irregularity in the error in the Moon's mean longitude. Whilst the tables

are rapidly falling away from the observed place of the Moon, the rate at which this occurs fluctuates in an inexplicable manner. This is well shown in Professor Newcomb's paper announcing the discovery of the new term due to the action of *Jupiter*. The two most marked breaks occur between the years 1867–1868 and 1870–1871. For this reason I have judged it best to determine $\delta\epsilon$ separately for each year from the observations of that year.

The terms depending on the errors in the coefficients of the annual equation, and on the perigee term (w = twice the distance of the Sun from the perigee of the lunar orbit), have been introduced for theoretical reasons. It is never safe to assume that the errors of a term of half the period of the particular term which may be being determined will destroy each other in the course of a short number of observations. For this reason the term depending on δW has been introduced. A similar remark applies to the annual equation which has a period only one-ninth shorter than the parallactic term to be determined. My main reason for introducing this term was, however, the fact that my researches had shown me that Hansen's coefficient was faulty, so that it might be expected to exercise some influence.

The final equations were reduced to the system

$$\begin{aligned} 926{\cdot}15\,\delta Q + 21{\cdot}30\,\delta W + 122{\cdot}74\,\delta M &= +\ 29{\cdot}16'', \\ 33{\cdot}54\,\delta Q + 923{\cdot}37\,\delta W + 66{\cdot}61\,\delta M &= -1016{\cdot}29'', \\ 90{\cdot}71\,\delta Q + 59{\cdot}01\,\delta W + 948{\cdot}84\,\delta M &= +\ 25{\cdot}82'', \end{aligned}$$

which on solution gives the result

$$\begin{aligned} \delta Q &= +0{\cdot}175'', \\ \delta W &= +0{\cdot}101'', \\ \delta M &= -1{\cdot}061''. \end{aligned}$$

At first sight it would appear that Hansen's value of the annual equation ought to be increased by over a second of arc, but it must be remembered that the effect of determining $\delta\epsilon$ in the foregoing manner merges the effect of the year's variation in the Moon's mean longitude into the correction to the annual equation. The value of δM really includes both the total correction to the annual equation and a portion of the correction to Hansen's motion in mean longitude.

In forming sin q it has been found convenient to put

$$\sin(\theta - \alpha) = -\sin(-\theta + \alpha) = -\sin(l' - A),$$

where l' denotes the mean longitude of the Sun, and A the mean longitude of the lunar perigee. Q is therefore equal to the coefficient of the term

$$\sin(\theta - \alpha)$$

with its sign reversed. The above result indicates therefore that Hansen's value of this coefficient ought to be increased by 0″·175, a very considerable increase. From Hansen's *Darlegung* it appears that he has assigned to Q, the coefficient of this term, the value (with its sign reversed)

$$Q = +18''\cdot492 \times 1\cdot03573$$
$$= +19''\cdot152$$

The effect of the correction deduced from observation would be to raise this to the value

$$Q + \delta Q = +19''\cdot327.$$

It remains to see what effect this change will have in altering Hansen's value for the solar parallax.

For convenience let it be supposed that the solar parallax is 8″·75 and that the Moon's mass is $\frac{1}{81\cdot5}$. Then, according to Delaunay, the coefficient of this term ought to be 18″·56, or, as I should make it from his data,

$$Q = 18''\cdot578,$$

for he appears to have underestimated the value of the remainder of his series.

Pontécoulant finds for this term the value 18″·41, or rather, from the analytical results of Pontécoulant's *Théorie de la lune*, this value can be deduced, employing the above data, which differs from that made use of by him. But Pontécoulant's coefficient is admittedly deficient in terms involving high powers of e and γ. Supplying these corrections, and allowing for an error which he afterwards detected, his coefficient becomes

$$Q = 18''\cdot54.$$

I have made sufficient advance in my own theory to be enabled to supply the principal part of this coefficient from my own researches. The coefficient has the value

$$Q = \Big\{\frac{165}{32}m + \frac{5997}{256}m^2 + \frac{98049}{1024}m^3 + \frac{8457917}{16384}m^4 + \frac{193186623}{65536}m^5$$
$$+12''\cdot0786 \quad +4''\cdot4367 \quad +1''\cdot4727 \quad +0''\cdot6397 \quad +0''\cdot2953$$
$$+\frac{87648232497}{524288}m^6 + \ldots\Big\} b^2 e \cdot \frac{1-\lambda}{1+\lambda} = 19''\cdot0584\,\frac{1-\lambda}{1+\lambda},$$
$$+0''\cdot1354$$

where m is as usual equal to $\frac{m}{1-m}$, λ is the mass of the Moon, and b^2 stands for the quantity of the second order $\frac{a}{a'}$, the ratio of the distances of the Sun and Moon. I am not quite sure of the last term being perfectly complete, as it is an order beyond the usual extent of my computations, and I have not yet quite completed this portion. It will be seen that this series converges appreciably quicker than that made use of by Delaunay. Adding to this coefficient the portion necessary to complete the preceding series (= 0″·0870), supplying from Delaunay the terms depending on the higher powers of e which I have not yet determined, and replacing λ by its value, the value of this coefficient becomes

$$Q = 18''\cdot5290.$$

All these values agree closely, and there is little doubt but that the value

$$Q = 18''\cdot550$$

is very close to the truth.

There is no difficulty in determining the coefficient of this term with any needed accuracy, for it would not be difficult to push the calculation to the order m^{10}, or, by numerical solution, to determine its value to 0″·001.

It appears, however, that the value indicated by observation exceeds this theoretical quantity by

$$+0''\cdot777,$$

and if this were really the true value of this coefficient as shown by the observations, it would correspond to a solar parallax of

$$9''\cdot117;$$

this is impossible.

It does not appear possible that there should be anything erroneous in the method of deducing this correction. It might be thought that the method of correcting the equations of condition for errors of longitude and epoch might introduce some systematic error. For this reason the observations were reduced anew in their unaltered form, determining both δl and $\delta\varepsilon$ from the total 1,464 observations. The values obtained were

$$\begin{aligned}
\delta Q &= +0''\cdot187,\\
\delta W &= +0''\cdot140,\\
\delta M &= -0''\cdot586,\\
\delta l &= +0''\cdot985,\\
\delta\varepsilon &= 1864''\cdot1.
\end{aligned}$$

These are practically identical with those previously obtained.

I think I shall be able to throw some additional light on this perplexing discrepancy when I have completed my determination of the theory of the terms of long period in the Moon's mean longitude. I am also reducing the Altazimuth observations of the Moon made at Greenwich, and the Washington Transit Circle observations.

I bring the question before the Society because it is important that such things should be made known, and because it throws a good deal of light on the high value of the solar parallax deduced by Hansen. When I commenced my inquiry I believed that I was the first to suggest the employment of this inequality of long period for the determination of the solar parallax. I think I am the first who has explicitly directed attention to its capabilities, and especially to its apparent freedom from systematic error, but I now believe that Hansen had made use of it for this purpose, and that it was mainly from this inequality that he determined the high value assigned by him to the solar parallax, and necessarily to the parallactic inequality. Hansen has nowhere explicitly referred to his having made use of this term for this purpose, but a paragraph in an early paper of his leaves little doubt on the matter, and this view is confirmed by several remarks in his *Darlegung*. The paragraph referred to occurs in a letter in the *Monthly Notices*, vol. xv., p. 9, and is as follows:—

'I may remark further that I have taken into consideration, not only the coefficient of the parallactic inequality itself, but also the largest of the remaining terms depending on the Sun's parallax, and that the aggregate of these terms may amount to the fifth part of the coefficient of the parallactic inequality.'

The first clause would seem clear enough, but the last renders it rather perplexing; for the sum of the three principal minor terms of the parallactic inequalities amount to not one-fifth, but two-fifths of the coefficient of the parallactic inequality. I am not certain, therefore, whether Hansen in this paragraph really alludes to this term of long period, or merely to the two other terms, which, having arguments of short period, are more naturally associated with the parallactic inequality, and the sum of the coefficients of these two terms would amount to one-fifth of the coefficient of this term. I have little doubt but that, subsequently, he did make use of this term of long period, from the tenor of his remarks in the *Darlegung*, though there is no explicit statement of the fact.

As Hansen's Tables now indicate a marked diminution of his coefficient of the parallactic inequality, his making use of this term would serve to explain how he came to render his value too great. Its apparent independence from systematic error would naturally lead to greater weight being attached to its results.

From the second system of equations it appears that Han-

sen's value of the coefficient of the annual equation ought to be increased by more than half a second, although it is already a far larger value than has been arrived at by any other theorist. Hansen's value is 669″·880, whilst Delaunay finds 668″·910, and Pontécoulant 668″·932. I have not yet completed my own result, but I anticipate it will considerably exceed those of both Delaunay and Pontécoulant. It is, however, very desirable to determine the observed value of the annual equation, as it has an important bearing on the value of the parallactic inequality and variation. Moreover, its determination from observation is exposed to a systematic error tending to increase its apparent magnitude, and it is this augmented value which must be considered in discussing the observed place of the Moon with the view of deducing corrections to the other inequalities.

For this reason I was led to more carefully examine the correction required by Hansen's value of this coefficient. The observations were grouped into the three periods 1862–1867, 1868–1870, and 1871–1876, so as to avoid the effect of the sudden changes in the apparent mean motion which made its appearance between 1867–1868 and 1870–1871. These groups were then separately solved in the usual manner, and three accordant values were obtained for the correction to the coefficient of the annual equation. The final result from the three is

$$\delta M = -0''\cdot7294 \pm 0''\cdot0712,$$

and is the result of the reduction of 1,464 observations made with the Greenwich Transit Circle between the years 1862–1876. When thus augmented the coefficient of the annual equation becomes

$$M = -670''\cdot609.$$

This result is greater than any which has been obtained from pure theory, unless Damoiseau's value of 673″·70 be considered as a purely theoretical value. Burckhardt, from observation, found the value 673″·3, but his Tables show this value to be too great. The Astronomer Royal, in his discussion of the Greenwich Observations between 1750 and 1850, was led to the value 670″·04, but considered this value probably too large. In the American Tables the coefficient 670″·3 is employed, and the comparison between the Washington Observations and these Tables shows that it cannot be seriously in error; whereas the comparison between Hansen's Tables and the Greenwich Transit Circle observations at once indicate that there is a discrepancy between the tabular and observed value of this coefficient.

The introduction of these corrections goes far to reduce the apparent irregularities in the motion of the Moon's mean longitude. The rate at which the tables are deviating from the true place of the Moon seems to be decreasing, and to correspond to a

considerable extent to the effect of the faulty determination of the terms of long period in the Moon's mean motion arising from the action of the planet *Venus*.

In a subsequent communication I trust to be able to give a new determination of the parallactic inequality, in which the effects of the variation of the Moon's semi-diameter will be independently determined, and which shall be free from the objection which I think can be urged against the sufficiency of the theoretical basis of the previous determinations. I trust also to be able to remove the remaining irregularities in the apparent motion of Hansen's mean longitude, by tracing them to their source.

The Radiant Points of April 9–12. By W. F. Denning, Esq.

In recently drawing out a Table showing the number of fireballs and bright meteors observed on each day of the year, I was surprised at the large number recorded on April 11–12, July 27–30, November 19, and December 21; and, with the object of finding the chief showers in action during the first of these special epochs, I have just completed the projection of more than 700 shooting stars registered by Zezioli in the years 1867–70, and by other Italian observers in 1869 and 1872. The radiant points derived from these tracks numbered 21, of which several appear to be of more than ordinary richness. The positions of these centres, compared with previous determinations and with Mr. Greg's Catalogue of 1876, are given in the following Table. The major radiants are at π *Herculis*, δ *Ursæ*, and α *Draconis* with more than 40 meteors each. The first of these agrees with two showers found by Schiaparelli from Zezioli's observations, and with one seen by Mr. Corder and the writer in 1877. The average of the four independently assigned centres is at $245^{\circ}{\cdot}7+51^{\circ}{\cdot}5$, which accords very closely with the new position at $249^{\circ}+51^{\circ}$. The maximum probably occurs on April 11, and the shower is no doubt connected (or included) with Mr. Greg's Draconids I at $263^{\circ}+50^{\circ}$ (No. 47). The shower at δ *Ursæ* is equally well defined, and it had been already recognised by Mr. Greg as an active and persistent display with a centre at $180^{\circ}+60^{\circ}$. The position at α *Draconis* (which also supplies several showers during the winter months) is not given in his Catalogue, but it falls near a strong radiant at $204^{\circ}+56^{\circ}$ (No. 55).. No. IV in the Table represents a conspicuous (though diffuse) centre of short meteors in *Coma Berenices*. The shower of Herculids (No. VII) appears to be sharply defined and distinct from several other April radiants near it, and this position may be regarded as very exactly determined from the following observations :—

April 9-12, 1879	257°+37°	25 meteors	D. and others.
April 2-23, 1868-9	256+38	4 radiants	S. and Z.
April 19, 1870	259+41	Stationary meteor	Schulhof.
April 21, 1874	259+38	Stationary meteor	Palisa.
April 20, 1873	257+34	Doubly obs. meteor	Waller.

The average position deduced from the five values is at 257°·6+37°·6. No. VIII at *β Ursæ* has apparently escaped all former observers, except Heis, who gives a very slightly observed shower at the same point, and it is probably different from a radiant further S. in *Ursa* at 162°+48° (Greg 56). A shower diverging from *β Ursæ* has been detected by Mr. Greg and others in the summer months; but, apart from Heis's confirmation of these April Ursids, the only good support given it is by a stationary meteor of the 2nd mag., recorded by Franzi, at Montcalieri, on May 9, 1872, at 163°+58°. Amongst the remaining showers indicated in the Table there are some certain radiants in *Boötes*, *Corona*, and near *η Ursæ*. No. XIII in *Cepheus* is new, and now requires further observation, and the system at 106°+46° in the Lynx, though not of remarkable intensity, appears to have supplied many of the brilliant meteors visible at this special period. One of the most accurately centred showers in the list is that between *α Serpentis* and *α Libræ* (No. XI, 228°−4°). The average of 7 radiants close to this point gives 227°·1−5°·7 as the resulting position which may be regarded as a very certain and exact April shower. There are a few diffuse radiants given in the Table; but these are of little value, as giving merely the general place of divergence of several mixed showers; for scattered or elongated radiants usually have their origin not so much in errors of observation of the path-directions from which they are derived, as from the contemporary activity of two or more bordering systems. Hence it is always important to note the visible features of each meteor as observed, so that those displaying similar characteristics may be arranged together, and disassociated from other streams, each of which it will be found has certain individual points of resemblance that will enable the observer to distinguish the true radiant in many cases.

The Radiant Points of April 9–12, derived from 700 Shooting Stars recorded by Zezioli and other Italian Observers in the Years 1867—1872, compared with previous Observations of the same Showers.

	W. F. Denning, 1879.			Other Observers.			Mr. Greg's Catalogue, 1876.		
No.	Remarks.	No. of Meteors.	Position. α δ	Position. α δ	Duration.	Observer.	No.	Position. α δ	Duration.
			° °	° °				° °	
I	Exact; Draconids I; max. April 11	44	249+51	246+46	Ap. 9	S. & Z. (51)	30, 40	249+45	Feb. 17—Mar. 3.
				240+55	Ap. 14	S. & Z. (58)			
				242+55	Ap.	Corder	47	263+50	Mar. 11—May 31.
				255+50	Ap. 16–19, 1877	D. 77, (41)			
II	Exact; α *Draconis*	43	212+65	210+66	Mar. 31—Ap. 12	D.S. III 19	55	204+56	Ap. 1—May 25
				202+62	May 1869	Serpieri			
III	Fairly exact; δ *Ursæ*; max. April 12	44	184+59	180+60	Mar. 3—Ap. 30	G. & H.	21, 46	180+56	Feb. 6—Ap. 25.
IV	Very diffuse; triple? 178+35, 184+28, 190+32	37	184+32	182+29	Ap. 29	S. & Z. (64)	54	190+24	Mar. 25—Ap. 30.
				198+32	Mar. 25—Ap. 24	G. & H.			
V	Radiant diffuse	26	218+13	217+16	Ap. 13—May 1	G. & H.*	53a	226+10	Ap. 1–30.
VI	Coronids	24	236+34	237+35	Ap. 30	S. & Z. (65)	67	235+23	Ap. 12—June 30.
VII	Exact; Herculids	25	257+37	256+38	Ap. 2–23	S. & Z. (49, 50, 60)	47	Positions of S. & Z. averaged with Draconids I (263+50) in Greg's Catalogue.	
VIII	At β *Ursæ*	24	162+59	162+59	Ap. 17–30	Heis, M_s.	56	162+48 Ap. 10–30	This shower is probably quite distinct from the β Ursids.
IX	S. of β *Leonis*	24	178+8	175+8	Ap.—May	Corder	28	175+14	Jan. 8—Mar. 31.
				175+10	Feb. 10—Ap. 2	G. & H.			

X	Exact; in 1869	19	123+40	123+40	Ap. 29—June 12	G. & H.	63	Only seen by G. & H.	
XI	Fairly exact	15	228− 4	228− 2 227− 8 227− 5	Ap. 16–19, 1877 Ap.—May Mar. 20—May 29	D. 77 (39) Corder G. & H.	53	225− 8	Mar. 20—May 29.
XII	Fairly exact	18	202+24	209+18	Mar. 2–3	Tupman (22)	29 39	205+17	Feb. 11—Mar. 3.
XIII	Exact	14	335+62	338+61	Mar. 31—Ap. 12	D.S. III 26	...	New shower in *Cepheus*.	
XIV	Near η *Ursæ*	19	205+43	206+44	Mar. 31—Ap. 12	D.S. III 15	55	204+56	Ap. 1—May 25.
	Uncertain	15	215+54	215+55 212+55	Mar. 30 Ap. 14	S. & Z. (45) S. & Z. (59)			
XV	In *Quadrans*	16	233+47	235+43	May 16—June 2	S. & Z. (67, 71, 77)	71	235+45	May 16—June 2.
XVI	Pair of diffuse radiants in *Serpens*;	13	230+15	230+ 5	Ap. 27, 28	Tupman (32)	41	248+12	Mar. 2–7.
	mean at 236+15	11	243+15	244+15	March 7	Tupman (19)			
XVII	Diffuse	13	226+25	218+22 221+20 223+23	Ap. 4—May 7 Ap. 21, 1872 Mar. 31—Ap. 12	Corder Denning D.S. III 29	53*a*	226+10	Ap. 1–30.
XVIII	Fairly exact	14	106+46	98+46	Mar. 19–27	G. & Z.	43	103+39	Mar. 9–27
XIX	Diffuse	10	288+41	284+44 294+41	Ap. 19–23	Denning	New showers not in Greg's Catalogue.		
XX	Exact	9	277+12	277+10	Mar. 31—Ap. 12	D.S. III 24			
XXI	Fairly exact	12	266+26	273+25 267+25	Ap. 13, 1864 Ap. 20, 1872	A. S. Herschel R. P. Greg	50	265+23	Mar. 2—Ap. 25.

A Catalogue of 222 Stationary Meteors. By W. F. Denning, Esq.

The following list of stationary meteors was compiled from the published Meteor Catalogues of Heis, Greg and Herschel, Schmidt, Weiss, Zezioli, Schiaparelli, Tupman, and Konkoly, and from the observations of Clark, Corder, Sawyer, Backhouse, Johnson, and myself. The annual reports of the Luminous Meteor Committee of the British Association were also consulted for the same purpose, and the positions selected from these materials will, it is thought, be of some value either as confirming old, or giving evidence of new, showers; though it is probable that many of the observations refer to meteors with extremely short paths, for unless an observer is looking exactly to that point of the heavens in which the meteor appears, he cannot certainly determine whether or not it is perfectly stationary. And in such cases of extreme foreshortening the nucleus is seen more or less projected upon the streak or offcome of sparks, giving it the appearance of a nebulous star, and rendering it difficult to detect the motion, if any, and assign the direction. Moreover a meteor, even if at the outset travelling in the observer's line of sight, will, as it encounters the variously dense atmospheric layers, sometimes appear to have a slightly curved or sinuous movement which cannot be accurately noted. In such cases the meteor is always very close to the radiant, though not necessarily in the exact centre of it; and it will be found that when several of these short meteors are recorded near the same radiant, their directions do not exactly correspond to the same point of departure as in the sketch (Fig. I.). The true radiant may, however, be found in the midst of these diverging tracks, the central positions of which it is generally easy to determine very accurately, for slowness of motion is a characteristic of these objects, and they leave very bright streaks or rather luminous clouds, especially when the apparition is visible in a region near the Earth's apex. The streaks or trains (visible as light patches) of these nearly stationary meteors are seen throughout their entire depth, and are thus apparently intensified to a considerable degree, whereas in the case of angular long-pathed meteors the streaks are seen only through their width, and their transient faint character is nearly always evident. In some instances where several meteors have been registered as quite stationary, and belong no doubt to the same radiant, there is a difference of a few degrees in their assigned positions which cannot be attributed to errors of observation. A diffused radiant area or the occurrence of two approximate showers might explain this anomaly,

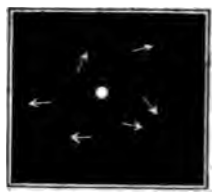

FIG. I.

but it is best accounted for on the supposition that the meteors were not without slight motion, though that motion was inappreciable to the eye. In the case of the August Perseids and April Lyrids there is a group of stationary meteors clustering around the radiant centre. In the instance of the former shower no less than 24 fixed meteors have been recorded between August 2 and 13, and their projected places conform to more than one radiant, as the following diagram (Fig. II.) shows most clearly:—

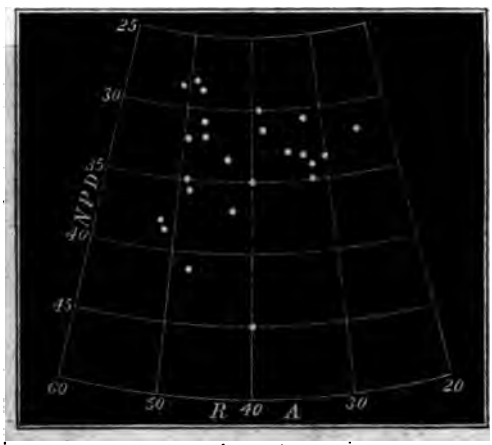

Fig. II.

There is a decided condensation near χ *Persei* and B–C *Camelopardi*, and a number of scattered positions extend in a southerly direction. Separating them into three groups and taking a mean of the observations, we have the following centres:—

I	$47^\circ + 59^\circ$	9 meteors	At B–C *Camelopardi*.
II	$32 + 57$	8 meteors	At χ *Persei*.
III	$46 + 51\frac{1}{2}$	7 meteors	At γ *Persei*.

The average of the 24 positions is at $42^\circ + 56^\circ$, which is close to Mr. Greg's general centre ($44^\circ + 56^\circ$) for the Perseids. Major Tupman's determination of this radiant is at $45\frac{1}{2}^\circ + 56^\circ$ (mean of 28 observations), and Heis gives the chief centre at $45^\circ + 51^\circ$ (A_{11} 425 meteors, August 1–24), which corresponds with No. III of the positions given above. (Two meteors, Nos. 107*a* and 127*a* in the Table, at $44^\circ + 56\frac{1}{2}^\circ$ and $45^\circ + 57^\circ$, August 9 and 10, confirm No. I; but these observations were erroneously omitted from the diagram, and also at first from the Table. Including them we have 26 stationary Perseids.) It is evident,

therefore, that these meteors prove, what has long been observed in connection with this rich stream, that its radiant is apparently diffused over the triangular region from χ *Persei*, γ *Persei*, and B–C *Camelopardi*. The origin of this diffusion probably lies in the fact that there are several concentric streams in simultaneous activity, and giving meteors exhibiting identical features.

The stationary meteors observed in the region of *Lyra* during the period from April 19–23 are more scattered than in the case of the Perseids, as shown in Fig. III.

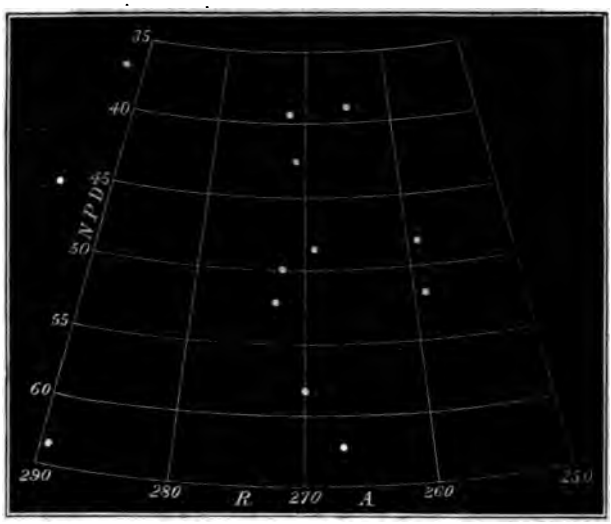

Fig. III.

If we might fairly assume that they all belonged to the Lyrids (the outlying positions being widely erratic members of the same system), then the average of the 14 observations gives a mean of 273°+40°, which, though evidently about 5° too far N., is in very fair accordance with this radiant as deduced by Mr. Greg at 272°+35° (No. 51 of his 1876 Catalogue). But the agreement is purely accidental, for the positions are much too distant to allow them to be justly incorporated into a common centre near the Lyrid meteor apex. There are probably 6 Lyrids amongst them with an average of 271°+35°, 3 Draconids, 269½°+50°* (= Mr. Greg's No. 47 at 263°+50° March 11–May 31), 2 Herculids, 259°+38½° (belonging to the special shower near π *Herculis* referred to in my paper on the Meteor

* The fireball of April 6, 1877, had a radiant point at 275°+50°, confirming this position.

Showers of April 9–12), 3 Cygnids near δ, β, and χ, the two former of which supply many shooting stars at this period.

Some of the alleged stationary meteors, especially those recorded in August, refer to the short bright streaks left in very foreshortened paths, and thus the positions given on the diagrams are somewhat scattered and erratic, but in the case of the Perseids (Fig. II.) there is no doubt that they are all members of that stream. Evidently in very rare cases only would a meteor be seen absolutely at rest like a star or planet, and the number of observations of fixed meteors must be extremely small as compared with those of meteors having paths of about $\frac{1}{2}°$ or 1°, and it is certain that a large proportion of the latter in which the motion escapes detection, must be mistaken for stationary meteors and described as such in Catalogues. Moreover the form of apparition of such objects renders them difficult of detection, unless they are very brilliant, or the observer chances to have his gaze directed towards the place of appearance. Ordinary meteors, by their motion amongst the stars, attract the eye directly, but the smaller class of fixed meteors are very liable to elude detection, especially when visible in a region of bright stars.

A stationary meteor will sometimes appear in a point of the sky from whence no other meteors are directed on the same night. Such an observation acquires additional value from the fact that it affords exact evidence of a very feeble shower, and one of which the radiant could only be derived from long observation. Active showers are readily ascertained from the backward intersection of the usual angular meteors; but attenuated systems will long avoid discovery, as they may only give a solitary member during a whole night's watch. Too much value should not, however, be given to extremely short or stationary meteors when close on the horizon, for the effects of perspective and atmospheric refraction on meteors falling vertically at very low altitudes are such as to cause an extreme contraction of the apparent paths.

The list includes a large number of stationary meteors for April 19–23, July 26–31, and August 8–13, and it might be inferred that at these special epochs there is an actual preponderance of such objects. The fact is, however, that at each of these periods the sky has been watched with unusual diligence, and amongst the multitude of meteors recorded, the number observed to be stationary is considerably in excess of those noted at other seasons, when the aggregate extent of observation has been far less. In order to determine the relative monthly proportion of meteors of all kinds registered by different observers, I recently summarised the results given in twelve Catalogues, which comprise 59,086 meteors, and the following numbers were derived:—

January	2419 ↓s	July	7369 ↓s
February	1609 „	August	23374 „
March	1449 „	September	2897 „
April	4324 „	October	4827 „
May	1133 „	November	5457 „
June	1325 „	December	2903 „

Thus August alone contains as nearly as possible 2-5ths of the total number of observations. The figures for July are also large, and nearly 1-8th of the whole. In August very few records exist for the last half of the month, but in July the bulk of the meteors were seen on the last six nights. The epochs of the Orionids (Oct. 18–20), Leonids (Nov. 13), and Geminids (Dec. 9–12) have each a mass of registered tracks and many stationary meteors. The night of August 10 is the chief one of the year, for more observations have been made on this date than on any other. Apart from the Perseids there is not any specially intense shower, but there are more than 60 distinct meteor radiants visible on that one night alone, and this is but a small minority of the whole number, active and feeble, in action; and thus we may perhaps form some remote idea of the myriads of such streams encountered by the Earth in her annual path.

Close and frequent repetitions in the radiant points of many recent fireballs have been found by Professor Niesal from calculations of their real paths,* and I had myself noticed, both from observation and reduction, many exact agreements in the radiants of successive meteor displays, so that a duration of one, two, and even three months appeared probable in many instances; though that such showers are physically identical is impossible on the assumption that meteor streams pursue parabolic orbits and are necessarily of extremely brief duration, as Lyrids, Leonids, and Andromedes. But these condensed periodical displays are of exceptional character and cannot be held typical of the very numerous and scattered systems which annually recur without any great variation. Feebleness and long duration appear to be their special features as opposed to the transient intensity of the true cometary meteor showers, and it has occurred to me that the present list of stationary meteors might furnish another indication of the long endurance of certain radiant points, for there are many examples of repetition occurring in the list. Thus Nos. 84 and 165, July 28 and Sept. 26, are identical at δ *Draconis*, and there is, singular to say, a very sharply defined radiant here during the period from June 26 to Oct. 31 (127 days). 14 observations by Heis, Greg and Herschel, myself, and others give a radiant at 290°·6+69°·7 (+ 300 meteors), and the positions agree so well that a circle of 5° diameter will include the whole of them

* *Monthly Notices*, vol. xxxix, p. 281.

Now if we are to allow 3 or 4 nights only as the theoretical limiting period of a shower's activity, then this conspicuous shower of Draconids must consist of 30 or 40 different streams directed from the same point near *δ Draconis*! We know that the number of meteor streams must be very great and frequently supplement each other at short intervals so as to give several successive showers of coincident position; but it is very curious that this radiant—and many others—is so exactly and fully exhibited over so long a range of time. Any attempt to disentangle it into a large number of short-lived showers with their periods will defy the most accurate and lengthy observation. Another instance of similar nature occurs in the early part of the year in the case of a shower S. of *α Leonis*, to which belong the stationary meteors, Nos. 16 and 21, at 145°+8°, Feb. 24, and 146°+9°, April 3. This radiant apparently sustains a persistent display from the end of November until the beginning of April, from a centre at 145°+6°. A few other good accordances of stationary meteors may be mentioned. Nos. 191, 208, and 218, Nov. 4, 18, and Dec. 10 have an average position at 133°+47° (*ι Ursæ Majoris*). Nos. 174, 199, and 209, Oct. 19, Nov. 12 and 21, at 125°+40° (*m Lyncis* of Bode). Nos. 29 and 111, April 19, Aug. 10, at 294½°+44° (*δ Cygni*). Nos. 160 and 214, Aug. 30, Nov. 28, at 9°+43° (*ν Andromedæ*), and Nos. 95 and 196, Aug. 4 and Nov. 10, at 213°+43½° (*η Ursæ Majoris*). No. 78, March 10, at 202°+42½° is also near the latter position. There are many other similar instances of repetition apparent in the Table, but they are not often exact, and indeed the whole of them may be explained on the supposition of different showers from the same directions, for it is obvious that many such accordances must naturally arise. Taken in conjunction with observations of the radiants of meteor showers and doubly observed meteors, these stationary meteors will, however, be found of great utility as regards the determination of both the duration and position of many shower centres. But radiant points that are *accurately* derived in the ordinary manner from a number of well observed tracks (including several much foreshortened near the centre) are in my own opinion preferable to those derived from either stationary or doubly observed meteors. So-called stationary meteors are seldom in the exact centre of a radiant point, and in regard to meteors (generally very bright) observed at several stations, the apparition is unexpected and seldom recorded accurately at more than one place by scientific observers thoroughly acquainted with the stars, and when the records are scanty and a little inexact, considerable doubt is at once thrown on the radiant position, which is not often to be relied on to within 5°. On the other hand, systematic watches maintained all night will yield most exact results, and tolerably active showers may have their centres assigned to within 2° of probable error. As observations accumulate of stationary and doubly observed meteors, and of ordinary meteor showers, it will be interesting to compare

the radiant points derived each way. This is already possible in several instances, amongst which the Lyrids Perseids, and Leonids may be mentioned as the best examples, for they also show exact accordances with cometary radiants. We may find a few similar cases occurring amongst the minor showers, one of which, that of the August Andromedes, is specified below:—

	Date.		Radiant.		
Aug.	10	1878	6° $+37^\circ$	shower of 5 meteors	Denning.
Aug.	3–16	1877	10 +38	shower of 16 meteors	Denning.
Aug.	21	1859	10 +39	stationary meteor	Heis.
Aug.	10	1871	7 +32	Doubly obs. meteor	Waller.
Aug.	14	—	$3\frac{1}{2}$ $+38\frac{1}{2}$	Comet II 1780 ♂	A. S. Herschel.

The number of meteors given in the Table is 222, distributed over the year as follows:—

Jan.	10	May	5	Sept.	7
Feb.	6	June	8	Oct.	22
March	4	July	26	Nov.	26
April	33	August	68	Dec.	7

The magnitudes are:—

> 1st	= 1st	= 2nd	= 3rd	= 4th and fainter	??	Total.
29	47	56	37	40	13	222.

Catalogue of 222 Stationary Meteors.

No.	Year (1800+) and Date.	Mag.	Position. R.A.	Dec.	Observer.	Place.	Observer's Notes.
			°	°			
1	67 January 2	1	228	+55	Bornitz	Lichtenberg	Leuchtender Punkt.
2	79 January 3	3	137	+ 7	Sawyer	Cambridge, Mass.	Stationary meteor. [*See* No. 5.]
3	77 January 9	>1	164	−15	Denning	Bristol	White. ? if stationary.
4	71 January 12	1	144	−23	Wiener	Athens	[Stationary meteor.]
5	74 January 20	3	136	+ 5	Corder	Writtle	Uncertain in R.A. to a few degrees.
6	52 January 25	1	117	+38	Heis	Aachen	Leuchtender Punkt.
7	70 January 25	3½	22·9	+59·8	Schulhof	Wien	Mitte einer sehr kurzen Bahn.
8	70 January 26	3	10·8	+49·4	Schulhof	Wien	Fast stationäres Meteor. [*See* No. 156.]
9	78 January 28	2	162	+ 3	Sawyer	Cambridge, Mass.	Stationary meteor.
10	78 January 28	4	119	− 6	Sawyer	Cambridge, Mass.	Stationary meteor.
11	57 February 17	2	132	+38	Heis	Münster	Plotzliches Aufleuchten einer Stelle.
12	69 February 17	5	181	− 9	Schmidt	Athens	[Stationary meteor.]
13	68 February 17	?	222	+ 7	Zezioli	Bergamo, Italy	Comparve come brevissimo lampo, impossibile comprenderne la direzione, lasciò bianco 5 secondi.
14	69 February 22	3	217	−41½	Tupman	Mediterranean	Stationary at η *Centauri*.
15	70 February 23	3	33·8	+36·5	Schulhof	Wien	Röthliches, stationäres Meteor.
16	78 February 24	4	145	+ 8	Sawyer	Cambridge, Mass.	Stationary meteor. [*See* No. 21.]
17	78 March 5	>1	189	−11	Backhouse	Sunderland	? Stationary. Seen through gap in clouds.

No.	Year (1800+) and Date.	Mag.	Position. R.A.	Dec.	Observer.	Place.	Observer's Notes.
			°	°			
18	70 March 10	1	202	+42·5	Zezioli	Bergamo	Punto lucido senza movimento sensibile: apparve e sparì come un lampo.
19	65 March 17	3	305	+77	Herschel	Hawkhurst	Almost stationary at κ *Cephei*.
20	63 March 18	1	208·2	+33·4	Crumplen	London	No path. Stationary. 1 second.
21	72 April 3	2	146	+ 9	Zona	Caltanisetta, Italy	Impiegò un secondo nel corso.
22	53 April 5	1	37·5	+53	Heis	Münster	Momentanes Aufblitzen.
23	70 April 5	2	237·0	+ 4·3	Palisa	Troppau	Sehr kurze Bahn. Fast stationär.
24	74 April 6	2	206	−18	Wiener	Athens	[Stationary meteor.]
25	79 April 11	6	75	+45·5	Cornish	Debenham, Suffolk	Stationary meteor. 1½ second.
26	50 April 13	1	251	+74	Heis	Aachen	Heller Lichtpunkt.
27	70 April 19	1	270·1	+31·4	Schulhof	Wien	Fast stationäres Meteor. [Lyrid.]
28	70 April 19	1	258·9	+41·4	Schulhof	Wien	Stationäres Meteor. Dauer 2 seconds. [Herculid.]
29	73 April 19	1	295	+44	Clark	Street	Slight cloud, 1½ sec. Stationary.
30	70 April 19	2	272·1	+50·7	Palisa	Troppau	Stationäres Meteor. [Draconid.]
31	70 April 19	2	289·4	+26·4	Palisa	Troppau	Stationäres Meteor.
32	74 April 19	4	278·8	−28·9	Palisa	Pola	Mitte kurzer Bahn.
33	67 April 20	3	265	+51	Bornitz	Lichtenberg	Leuchtender Punkt. [Draconid.]
34	70 April 20	1	266·7	+27·7	Littrow	Wien	Stationäres Meteor.
35	70 April 20	2	20·6	+55·6	Oppolzer	Wien	Mitte sehr kurzer Bahn. [*See* Nos. 7 and 110.]
36	70 April 20	3	292·7	+52·3	Oppolzer	Wien	Mitte sehr kurzer Bahn.

37	74	April 20	4	223·4 − 5·8	Schulhof	Wien	Stationäres Meteor.
38	74	April 20	1	245 + 11	Clark	Heidelberg	Almost stationary. Path ½° to 245½° + 11¼°.
39	70	April 21	2	225 + 69	Oppolzer	Wien	Fast stationäres Meteor.
40	70	April 21	8	251·9 + 14·7	Oppolzer	Wien	Mitte einer sehr kurzen, im Kometensucher gesehenen Bahn.
41	70	April 21	3	175·8 + 19·3	Littrow	Wien	Stationäres Meteor.
42	70	April 21	4	272·8 + 40·1	Palisa	Troppau	Stationäres Meteor. [Lyrid.]
43	74	April 21	4	258·9 + 38·1	Palisa	Pola	Stationäres Meteor. [Herculid.]
44	74	April 21	4	271·1 + 47·3	Felgel	Brünn	Fast ganz stationäres Meteor.
45	70	April 22		218·0 + 8·4	Littrow	Wien	Fast stationäres Meteor. Im Kometensucher gesehenes.
46	70	April 22	6	269·4 + 41·2	Littrow	Wien	Mitte einer sehr kurzen Bahn. [Lyrid.]
47	74	April 22	3	260·4 + 59·3	Palisa	Pola	Stationäres Meteor.
48	74	April 22	4	248·8 + 6·1	Palisa	Pola	Fast stationär.
49	70	April 23	1½	199·8 + 69·8	Littrow	Wien	Stationäres Meteor.
50	70	April 23	2½	262·4 + 32·3	Palisa	Troppau	Stationäres Meteor. [Lyrid.]
51	70	April 23	4½	273·4 + 37·3	Palisa	Troppau	Stationäre Meteor. [Lyrid.]
52	70	April 23	> 1	218 − 3	Zezioli	Bergamo	Aparve e sparì nello stesso sito.
53	68	April 28	1	194 + 12	Greg	Manchester	Nearly stationary at *ε Virginis*.
54	72	May 9	2	163 + 58	Franzi	Montcalieri	[At *β Ursæ Majoris*.]
55	72	May 15		191 + 47	Gerardini	Lodi, Italy	Stella immobile nel punto assignato.
56	77	May 15	2	256 + 5	Denning	Bristol	White; transient; stationary.

No.	Year (1800+) and Date.	Mag.	Position. R.A.	Dec.	Observer.	Place.	Observer's Notes.
			°	°			
18	70 March 10	1	202	+42·5	Zezioli	Bergamo	Punto lucido senza movimento sensibile: apparve e sparì come un lampo.
19	65 March 17	3	305	+77	Herschel	Hawkhurst	Almost stationary at *κ Cephei*.
20	63 March 18	1	208·2	+33·4	Crumplen	London	No path. Stationary. 1 second.
21	72 April 3	2	146	+ 9	Zona	Caltanisetta, Italy	Impiegò un secondo nel corso.
22	53 April 5	1	37·5	+53	Heis	Münster	Momentanes Aufblitzen.
23	70 April 5	2	237·0	+ 4·3	Palisa	Troppau	Sehr kurze Bahn. Fast stationär.
24	74 April 6	2	206	−18	Wiener	Athens	[Stationary meteor.]
25	79 April 11	6	75	+45·5	Cornish	Debenham, Suffolk	Stationary meteor. 1½ second.
26	50 April 13	1	251	+74	Heis	Aachen	Heller Lichtpunkt.
27	70 April 19	1	270·1	+31·4	Schulhof	Wien	Fast stationäres Meteor. [Lyrid.]
28	70 April 19	1	258·9	+41·4	Schulhof	Wien	Stationäres Meteor. Dauer 2 seconds. [Herculid.]
29	73 April 19	1	295	+44	Clark	Street	Slight cloud, 1½ sec. Stationary.
30	70 April 19	2	272·1	+50·7	Palisa	Troppau	Stationäres Meteor. [Draconid.]
31	70 April 19	2	289·4	+26·4	Palisa	Troppau	Stationäres Meteor.
32	74 April 19	4	278·8	−28·9	Palisa	Pola	Mitte kurzer Bahn.
33	67 April 20	3	265	+51	Bornitz	Lichtenberg	Leuchtender Punkt. [Draconid.]
34	70 April 20	1	266·7	+27·7	Littrow	Wien	Stationäres Meteor.
35	70 April 20	2	20·6	+55·6	Oppolzer	Wien	Mitte sehr kurzer Bahn. [*See* Nos. 7 and 110.]
36	70 April 20	3	292·7	+52·3	Oppolzer	Wien	Mitte sehr kurzer Bahn.

37	74	April 20	4	223·4 − 5·8	Schulhof	Wien	Stationäres Meteor.
38	74	April 20	1	245 + 11	Clark	Heidelberg	Almost stationary. Path ½° to 245½° + 11½°.
39	70	April 21	2	225 + 69	Oppolzer	Wien	Fast stationäres Meteor.
40	70	April 21	8	251·9 + 14·7	Oppolzer	Wien	Mitte einer sehr kurzen, im Kometensucher gesehenen Bahn.
41	70	April 21	3	175·8 + 19·3	Littrow	Wien	Stationäres Meteor.
42	70	April 21	4	272·8 + 40·1	Palisa	Troppau	Stationäres Meteor. [Lyrid.]
43	74	April 21	4	258·9 + 38·1	Palisa	Pola	Stationäres Meteor. [Herculid.]
44	74	April 21	4	271·1 + 47·3	Felgel	Brünn	Fast ganz stationäres Meteor.
45	70	April 22		218·0 + 8·4	Littrow	Wien	Fast stationäres Meteor. Im Kometensucher gesehenes.
46	70	April 22	6	269·4 + 41·2	Littrow	Wien	Mitte einer sehr kurzen Bahn. [Lyrid.]
47	74	April 22	3	260·4 + 59·3	Palisa	Pola	Stationäres Meteor.
48	74	April 22	4	248·8 + 6·1	Palisa	Pola	Fast stationär.
49	70	April 23	1½	199·8 + 69·8	Littrow	Wien	Stationäres Meteor.
50	70	April 23	2½	262·4 + 32·3	Palisa	Troppau	Stationäres Meteor. [Lyrid.]
51	70	April 23	4½	273·4 + 37·3	Palisa	Troppau	Stationäre Meteor. [Lyrid.]
52	70	April 23	> 1	218 − 3	Zezioli	Bergamo	Aparve e sparì nello stesso sito.
53	68	April 28	1	194 + 12	Greg	Manchester	Nearly stationary at *ε Virginis*.
54	72	May 9	2	163 + 58	Franzi	Montcalieri	[At *β Ursæ Majoris*.]
55	72	May 15		191 + 47	Gerardini	Lodi, Italy	Stella immobile nel punto assignato.
56	77	May 15	2	256 + 5	Denning	Bristol	White; transient; stationary.

No.	Year (1800+) and Date.	Mag.	Position. R.A.	Dec.	Observer.	Place.	Observer's Notes.
			°	°			
57	68 May 26	1	107	+67·5	Zezioli	Bergamo	Nel punto qui indicato apparve una luce maggiore che di 1ª grandezza senza direzione alcuna.
58	58 May 31	½ =)	285	+34	J. F. Herschel	Hawkhurst	Path of light its own size, .2 secs., same alt. as β and same azimuth as α *Lyræ*.
59	57 June 1	2 × 2	303	−14	Abbott	Hobart Town	Stationary between α and β *Capricorni*.
60	69 June 4	4½	331·0	+52·9	Rosner	Wien	Mitte sehr kurzer Bahn.
61	69 June 4	2	3·7	+67·0	Palisa	Wien	Mitte sehr kurzer Bahn. [*See* No. 82.]
62	77 June 4	1	323	+11	Esdaile	E. Grinstead, Sussex	A stationary fireball.
63	69 June 9	4	317·4	+45·7	Oppolzer	Wien	Mitte sehr kurzer Bahn. [Cygnid.]
64	69 June 9	4	291·3	+26·4	Rosner	Wien	Mitte sehr kurzer Bahn.
65	70 June 17	2	273	−28	Wiener	Athens	[Stationary meteor.]
66	70 June 28	1	290	−17	Wiener	Athens	[Stationary meteor. *See* No. 78.]
67	72 July 3	2	215	+16	Gerardini	Lodi	[Near *Arcturus*.]
68	67 July 4	6	255	+63	Zezioli	Bergamo	[Six stars with short paths appeared here at small intervals.]
69	62 July 21	2	8	+20	Bornitz	Lichtenberg	Leuchtender Punkt.
70	78 July 21	3	76	+54	Denning	Bristol	Almost stationary. [Aurigid.]
71	54 July 25	5	344	+42·5	Winnecke	Göttingen	Leuchtender Punkt.
72	67 July 26	1	244	+43	Zezioli	Bergamo	Più chiara di Wega, come lampo apparve e scomparve nel medesimo punto.

73	70	July 26	2	350·0 + 47·1	Palisa	Wien	Fast ganz stationäres Meteor.
74	70	July 26	2	359·4 + 48·6	Strasser	Kremsmünster	Mitte sehr kurzer Bahn.
75	70	July 26		140·7 + 78·7	Strasser	Kremsmünster	Mitte sehr kurzer Bahn.
76	70	July 26	4	308·4 + 4·7	Felgel	Brünn	Mitte der Bahn eines sehr kurzen.
77	70	July 26	3	30·3 + 47·2	Bartel	Brünn	Mitte der sehr kurzen Bahn. [Perseid II.]
78	70	July 26	> 1	296 − 14	Herschel	Hawkhurst	Almost stationary. Moved slightly west.
79	54	July 27	½	37·5 + 48	Winnecke	Göttingen	Sehe man unten nach. [Perseid II.]
80	73	July 27	4	359·5 + 52·2	Nagy	O'gyalla	Stationäres Meteor.
81	76	July 27	3	336·4 + 66	Konkoly	O'gyalla	[Stationary meteor.]
82	51	July 28	1	12 + 76	Billerbeck	Rastenburg	[Stationary meteor.]
83	65	July 28	2	284 + 70	Herschel	Hawkhurst	Very short. Nearly stationary.
84	65	July 28	2	290 + 67·5	Herschel	Hawkhurst	Stationary close to δ *Draconis*.
85	78	July 28	3	38 + 32	Denning	Bristol	Very short. Streak 3 secs.
86	78	July 28	4	341 + 51	Corder	Writtle	Path ½° to 342° + 51°. Lacertid.
87	78	July 29	3	304½ + 23	Corder	Writtle	Path ½° to 305° + 22¾°.
88	70	July 29		351 + 18	Palisa	Wien	Stationäres Meteor.
89	75	July 31	4	295·3 + 52·2		O'gyalla	Path ½° to 295°·1 + 52°·0.
90	56	July 31	♀	336 − 6	Heis	Münster	Leuchtender Punkt, röthlich. [*See* No. 92.]
91	56	July 31	2	38 + 38	Heis	Münster	Leuchtender Punkt.
92	59	July 31	3	341 − 8½	Schmidt	Athens	[Stationary meteor.]

No.	Year (1800+) and Date	Mag.	Position. R.A.	Dec.	Observer.	Place.	Observer's Notes.
			°	°			
93	78 August 2	2	32	+55	Denning	Bristol	Stationary at χ *Persei*. 3 secs.
94	67 August 2	6	40	+45	Heis	Münster	Leuchtender Punkt.
95	61 August 4	4	215	+42	Heis	Münster	Hell leuchtend blau ohne Bahnstrecke.
96	64 August 5	♀	44	+57	Heis	Münster	Leuchtender Punkt. [Perseid.]
97	69 August 5	2	100·1	+66·9	Felgel	Wien	Mitte einer sehr kurzen Bahn.
98	72 August 5	3	33	+33	Lorenzoni	Padova	Un punto.
99	70 August 6	♀	42	+75	Greg	Manchester	Stationary meteor. 4 secs. [*See* No. 112.]
100	71 August 8	1	38	+34·5	Waller	York	Quite stationary. Luminous cloud for 1½ sec. over ¼°. [*See* No. 85.]
101	78 August 8	4	353	+42	Corder	Writtle	Stationary meteor. [*See* No. 73.]
102	64 August 8	1	59	+70	Heis	Münster	Leuchtender Punkt. [*See* No. 119.]
103	76 August 8	3	35	+57	Denning	Bristol	Meteoric luminosity 1½ sec. [Perseid.]
104	61 August 8	>1	117	+64	Airy	Ipswich	A stationary flash.
105	69 August 9	1	73	+61	Herschel	Hawkhurst	Very short path ½ sec. A sudden flash. [Approximate.]
106	76 August 9		347	+26	Backhouse	Sunderland	Rather uncertain. [Pegasid I.]
107	72 August 9	1	39	+60	Clark	York	Almost perfectly stationary. [Perseid.]
107*a*	78 August 9	3	44	+56½	Sawyer	Cambridge, Mass.	Stationary. Accurate. [Perseid.]
108	50 August 9	1	43	+53	Heis	Aachen	Leuchtender Punkt. [Perseid.]
109	66 August 9	2	27	+21	Heis	Münster	Leuchtender Punkt.
110	50 August 10	1	25	+58	Heis	Aachen	Sehr heller Lichtpunkt. [*See* Nos. 7, 35, and 186.]

111	73	August 10	1	294 +44	Heis	Münster	Leuchtender Punkt.
112	63	August 10	2	51 +75	Heis	Münster	Leuchtender Punkt. [*See* Nos. 99 and 102.]
113	64	August 10	3	40 +55	Heis	Münster	Leuchtender Punkt. [Perseid.]
114	72	August 10	3	48·8 +62·0	Schulhof	Wien	Stationäres Meteor. [Perseid.]
115	72	August 10	2	216·5 +38·1	Schulhof	Wien	Blos Anfangspunkt beobachtet.
116	72	August 10	4	43·1 + 1·8	Schulhof	Wien	Stationäres Meteor.
117	72	August 10	3	48 +49	Maggi	Volpeglino, Italy	Si spegne senza far cammino. [Perseid.]
118	72	August 10	1	76 +46	Maggi	Volpeglino	Si spegne senza far cammino. [Aurigid, *see* No. 137.]
119	74	August 10	5	55·1 +69·6	Konkoly	O'gyalla	[Stationary meteor. *See* No. 102.]
120	77	August 10	4	38 +58·5	Denning	Bristol	A stationary Perseid.
121	72	August 10	–	51 +61·5	Serpieri	Urbino	[A stationary Perseid.]
122	77	August 10	2	63 +46	Johnson	Crediton	White; almost stationary; below μ *Persei*.
123	69	August 10	1	337 +78	Backhouse	Sunderland	Stationary at 28 *Cephei*; yellow.
124	70	August 10	2	32 +56	Backhouse	Sunderland	Stationary. [Perseid.]
125	61	August 10	2	258 +15	Crumplen	London	Stationary, 1° E. of α *Herculis*.
126	68	August 10		18 +32	Lucas	Oxford	Below β *Andromedæ*; no motion.
127	68	August 10	>1	32 +56	Lowe	Beeston, Notts	Appeared and disappeared without motion; 40′ in diameter.
127*a*	74	August 10	3	45 +57	Clark	Birmingham	Stationary; white. Train 1½ sec. [Perseid.]
128	78	August 10	3	47 +58	Corder	Writtle	Stationary. [Perseid.]

No.	Year (1800+) and Date.	Mag.	Position. R.A.	Dec.	Observer.	Place.	Observer's Notes.
129	76 August 10	2	49½	+58	Tupman	St. Moritz	Almost stationary; slight motion. [Perseid.]
130	72 August 10	3	49	+55	Serpieri	Urbino	Path ½° to 49½° + 54°·7. [Perseid.]
131	74 August 10	2	51½	+51¾	Clark	Birmingham	Path ½° to 52° + 51½°. [Perseid.]
132	77 August 10		30·1	+56·1	Schrader	O'gyalla	Path ¾° to 29°·5 + 55°·5. [Perseid.]
133	69 August 11	3	48½	+54½	Backhouse	Sunderland	Very short; direction imperceptible. [Perseid.]
134	77 August 11	2	52	+52	Johnson	Crediton	Nearly stationary. [Perseid.]
135	72 August 11	3½	279·8	+41·3	Schulhof	Wien	Mitte einer sehr kurzen Bahn.
136	69 August 11		47·5	+59·3	Tupman	Mediterranean	Stationary Perseid.
137	63 August 12	2	80	+43	Heis	Münster	Aufleuchtend. [Aurigid.]
138	72 August 12	2	211·2	+34·5	Schulhof	Wien	Stationäres Meteor; orange färbiges.
139	69 August 12	1	3	−9	Backhouse	Sunderland	At ι *Ceti*; stationary; yellow.
140	69 August 12	4	96·9	+55·3	Rosner	Simmering	Path ½° to 98°·1 + 55°·3.
141	76 August 12	2	32½	+58¾	Clark	York	Centre of path of only ½°. [Perseid].
142	67 August 13	♀	314	−8	Heis	Münster	Ohne Bewegung aufblitzend.
143	69 August 13	2	201·3	+55·3	Oppolzer	Wien	Mitte einer sehr kurzen Bahn.
144	69 August 13	5½	299·4	+10·2	Littrow	Wien	Mitte einer sehr kurzen Bahn. [Aquilid.]
145	69 August 13	2	48·7	+61·5	Felgel	Wien	Stationäres Meteor. [Perseid.]
146	68 August 14	1	144	+55	Greg	Whitby, York	Nearly stationary; 1 sec.
147	68 August 15	1	194	+44	Greg	Whitby, York	Nearly stationary. Path 1° in ¾ sec.

148	57	August 16	2	337 + 9	Heis	Münster	Aufblitsend.
149	65	August 16	♀	272 −45·5	Wiener	Athens	[Stationary bolide.]
150	65	August 16	♀	338 −21·5	Wiener	Athens	[Stationary bolide.]
151	49	August 18	2	320 +63	Heis	Münster	Leuchtender Punkt der plötzlich verschwand.
152	59	August 21	2	10 +39	Heis	Münster	Punkt. [*Andromedes.*]
153	70	August 22	1	308·2 −20·3	Holetschek	Wien	Stationäres Meteor.
154	76	August 22	4	321½ + 9	Backhouse	Sunderland	Duration 0·5 sec. [*See* Nos. 62 & 162].
155	70	August 22	3	55·1 +26·6	Borutsky	Schram	Path ½° to 55°·8 + 26°·6.
156	71	August 25	2	9 +49½	Tupman	Mediterranean	Stationary meteor.
157	72	August 25	☽	10 + 7	Maggi	Volpeglino	[Stationary bolide.]
158	78	August 26	3	264 +12	Backhouse	Sunderland	Stationary; if motion, towards *α Ophiuchi* and about ½°.
159	65	August 27	♅	260 −41·5	Wiener	Athens	[Stationary bolide.]
160	73	August 30	9	8½ +41½	Backhouse	Sunderland	Seen in Equatoreal, power 38; path 12′ or 13′.
161	68	September 12	2	90 +70	Greg	Pitlochin	Very short; towards *Ursa Major.*
162	64	September 23	3	324 +12½	Herschel	Hawkhurst	Stationary; 1 second; white.
163	51	September 25	1	45 +40	Heis	Aachen	Leuchtender Punkt.
164	50	September 26	1	223 +27	Heis	Aachen	Leuchtender Punkt.
165	51	September 26	☽	292 +68	Heis	Aachen	Leuchtender Punkt; Feuerkugel.
166	51	September 27	1	10 −17	Heis	Aachen	Hell leuchtender Punkt.
167	78	September 29	1	15 + 3	Sawyer	Cambridge, Mass.	Orange; 1 sec.; approximate.

No.	Year (1800+) and Date.	Mag.	Position. R.A.	Dec.	Observer.	Place.	Observer's Notes.
			°	°			
168	78 October 1	4	8	+15	Sawyer	Cambridge, Mass.	Stationary; accurate.
169	77 October 2	2	302	+ 1·5	Backhouse	Sunderland	Orange; like a star or planet.
170	77 October 3	4	68	+33	Corder	Writtle	Stationary.
171	77 October 6	3	25	+18·5	Corder	Writtle	Stationary.
172	77 October 17	2	141	+28	Denning	Bristol	A stationary flash.
173	73 October 18	1·5	88·8	+76·7		Wien	[?? if stationary.]
174	74 October 19	5	128	+40	Backhouse	Sunderland	Stationary. [*See* Nos. 199 & 209.]
175	67 October 20	2	319	+19	Schmidt	Athens	[Stationary meteor.]
176	64 October 20	3	90	+70	Herschel	Hawkhurst	Nearly stationary; light patch 2 secs.
177	64 October 20	2	285	+63	Herschel	Hawkhurst	A stationary meteor. [*See* No. 198.]
178	78 October 20	2	355	+12·5	Sawyer	Cambridge, Mass.	Stationary 1 sec.; accurate.
179	78 October 21	4	39	−18	Sawyer	Cambridge „	Stationary; approximate.
180	78 October 22	1	24	− 1	Sawyer	Cambridge „	Stationary 1 sec.; seen through haze.
181	54 October 22	♀	272	+44	Heis	Münster	Leuchtender Punkt.
182	72 October 22	2	334	+61	Nagy	O'gyalla	Stationäres Meteor; bläulich weisses; durch 4 sec. sichtbares.
183	49 October 24	1	55	+45	Heis	Aachen	Leuchtender Punkt; röthlich; schw. 3 secund. sichtbar.
184	78 October 25	1	325	+38	Corder	Writtle	Stationary.
185	48 October 26	1	280	+24	Schmidt	Bonn	[Stationary meteor.]
186	69 October 27	2	17	+59	Clark	York	Path $\frac{1}{2}$° towards *Polaris*. $\frac{1}{2}$ sec.

187	78	October 29	2	31	+13·5	Sawyer	Cambridge, Mass.	Stationary; accurate.
188	67	October 29	½ = ☽	74	+62	Haly and Miller	Glasgow	Short curved path; 1 second. Approximate.
189	72	October 30		29	− 3	Backhouse	Sunderland	Uncertain observation. [*See* No. 180.]
190	59	November 2	1	231	+71	Lowe	Beeston, Notts	Four rapid flashes at same point. 20° below Polar Star. Approximate.
191	77	November 4	5	137	+47	Corder	Writtle	Stationary meteor. [*See* Nos. 208 & 218.]
192	77	November 7	1	338	−15	Johnson	Crediton	1° W. of τ *Aquarii*; no motion.
193	64	November 7	1	141	−11	Herschel	Hawkhurst	Stationary. Appeared to oscillate.
194	77	November 7	3	144	+42	Denning	Bristol	Stationary; light cloud; 3 secs.
195	63	November 9	♀	9	−18	Heis	Münster	Leuchtender Punkt.
196	49	November 10	1	211	+45	Schmidt	Bonn	[Stationary meteor. *See* No. 95.]
197	49	November 11	4	222	+64	Schmidt	Bonn	[Stationary meteor.]
198	49	November 12	3	287·5	+61·5	Schmidt	Bonn	[Stationary meteor. *See* No. 177.]
199	77	November 12	1	126	+40	Denning	Bristol	Stationary; small luminous cloud.
200	52	November 13	1	145	+61	Billerbeck	Rastenburg	[Stationary meteor.]
201	59	November 13	2	58	+12	Heis	Münster	Leuchtender Punkt. [*See* No. 211.]
202	66	November 13		149¾	+23¾	Backhouse	Sunderland	At ½ ($\mu-\gamma$ *Leonis*). Leonid.
203	70	November 13	2	150	+22½	Backhouse	Sunderland	Stationary like a fixed star. Leonid.
204	49	November 13	1	95	+24	Rath	Coln	Path ½° to 95° + 24½°.
205	66	November 14	♀	148	+25	Wood	Birmingham	Stationary body; 4 secs. Leonid.
206	66	November 14	>1	100	−17	Heinecken	Sidmouth	Stationary over *Sirius*.
207	75	November 15	1	158	+40	Nash	Greenwich	Almost stationary; path ½°.

Consequently

$$\sin^2 \tfrac{1}{2}v = \frac{\tan h' - \tan (\tfrac{1}{2}s - d')}{\tan \tfrac{1}{2}s - \tan (\tfrac{1}{2}s - d')}. \tag{3}$$

In the same manner

$$\sin^2 \tfrac{1}{2}V = \frac{\tan H' - \tan (\tfrac{1}{2}s - d')}{\tan \tfrac{1}{2}s - \tan (\tfrac{1}{2}s - d')}. \tag{4}$$

Substituting these values of $\sin^2 \frac{1}{2}v$ and $\sin^2 \frac{1}{2}V$ in (2),

$$d = d' - (\Delta h - \Delta H) + \frac{[\tan h' - \tan (\tfrac{1}{2}s - d')]\ \Delta h - [\tan H' - \tan (\tfrac{1}{2}s - d')]\ \Delta H}{\tfrac{1}{2}[\tan \tfrac{1}{2}s - \tan (\tfrac{1}{2}s - d')]} + \dots \tag{5}$$

or, putting

$$\tan h' - \tan (\tfrac{1}{2}s - d') = A,$$
$$\tan H' - \tan (\tfrac{1}{2}s - d') = B,$$
$$\tan \tfrac{1}{2}s - \tan (\tfrac{1}{2}s - d') = C,$$

this becomes

$$d = d' - (\Delta h - \Delta H) + \frac{A\Delta h - B\Delta H}{\tfrac{1}{2}C} + \dots \tag{6}$$

When (1) is transformed in the form

$$d = d' - \Delta h\,(2\cos^2 \tfrac{1}{2}v - 1) + \Delta H\,(2\cos^2 \tfrac{1}{2}V - 1) + \dots\ ,$$

or

$$d = d' + (\Delta h - \Delta H) - 2\,(\Delta h \cos^2 \tfrac{1}{2}v - \Delta H \cos^2 \tfrac{1}{2}V) + \dots\ , \tag{7}$$

an analogous deduction gives

$$\cos^2 \tfrac{1}{2}v = \frac{\tan \tfrac{1}{2}s - \tan h'}{\tan \tfrac{1}{2}s - \tan (\tfrac{1}{2}s - d')}, \tag{8}$$

$$\cos^2 \tfrac{1}{2}V = \frac{\tan \tfrac{1}{2}s - \tan H'}{\tan \tfrac{1}{2}s - \tan (\tfrac{1}{2}s - d')}. \tag{9}$$

Consequently,

$$d = d' + (\Delta h - \Delta H) - \frac{(\tan \tfrac{1}{2}s - \tan h')\ \Delta h - (\tan \tfrac{1}{2}s - \tan H')\ \Delta H}{\tfrac{1}{2}[\tan \tfrac{1}{2}s - \tan (\tfrac{1}{2}s - d')]} + \dots\ ; \tag{10}$$

or, putting

$$\tan \tfrac{1}{2}s - \tan h' = A',$$
$$\tan \tfrac{1}{2}s - \tan H' = B',$$

this is

$$d = d' + (\Delta h - \Delta H) - \frac{A'\Delta h - B'\Delta H}{\tfrac{1}{2}C} + \dots\ . \tag{11}$$

Since $\Delta d = d - d'$ is always $< 1°$, it is, in most cases, sufficiently correct to take the arcs to the nearest minute, and to perform the calculation with four-figure natural tangents.

When greater accuracy is required, especially when the altitudes are low and the distance small, the corrections of the second order (first deduced by Lexell*) may be taken into account, viz.

$$(12)\qquad \begin{cases} \frac{1}{2}(\Delta h^2 - \Delta d^2)\sin 1''\cot d' \\ + \dfrac{\cos(h'+H')\cos(h'-H')}{\cos h'\cos H'}\,\Delta h\Delta H \sin 1''\operatorname{cosec} d' \\ + \tan h'\tan H'\Delta h\Delta H \sin 1''\cot d' \\ + \frac{1}{2}\Delta H^2 \sin 1''\cot d'. \end{cases}$$

The first of these corrections, commonly called "the third correction," is contained in Chauvenet's *Spherical and Practical Astronomy*, ii. pp. 620, 621, as well as in almost all collections of nautical tables, and is thence easily applied. The other three corrections are, in low latitudes, generally very small, but in high latitudes cases are common in which the sum of these corrections is $> 10''$.

According to Legendre† the sum of all four corrections of the second order can be taken into account when Δd is recalculated with $d' + \frac{1}{2}\Delta d$, $h' + \frac{1}{2}\Delta h$, and $H' - \frac{1}{2}\Delta H$, viz. the given variables augmented with their half variations.

Example:

$d' = 51°\ 24'\ 45''$, $h' = 58°\ 56'$, $H' = 62°\ 45'$, $\Delta h = 30'\ 4'' = 1804''$, $\Delta H = 26''$.

By (6).

° ′				
51 25				
58 56	1·6599			
62 45		1·9416		
173 6				
86 33				16·5874
35 8	0·7037	0·7037		0·7037
	0·9562	1·2379		15·8837
	1804	26		
			° ′ ″	
			51 24 45	
	$\frac{1725-32}{7·942} = 213'' =$		+ 3 33	
			− 29 38	
			d = 50 58 40	

* *Act. Acad. Petr. p. A.* 1777. Petropoli, 1780, p. 348.

† *Mém. de l'Institut*, t. iv., 1805; and Delambre's *Astronomie*, t. iii., 1814, p. 625.

By (11).

° ′			
51 25			
58 56	1·6599		
62 45		1·9416	
173 6			
86 33	16·5874	16·5874	16·5874
35 8			0·7037
	14·9275	14·6485	15·8837
	1804	26	

	° ′ ″
	51 24 45
$-\frac{26929-381}{7·942} = -3343 =$	− 55 43
	+ 29 38
$d =$	50 58 40

The "third correction" is here only 1″·6, and the other corrections are evanescent.

The following formulæ are of the same class as (3), (4), (8), and (9):

$$\cos A = \frac{\cot(\frac{1}{2}s-b)+\cot\frac{1}{2}s-2\cot c}{\cot(\frac{1}{2}s-b)-\cot\frac{1}{2}s} = \frac{\cot(\frac{1}{2}s-c)+\cot\frac{1}{2}s-2\cot b}{\cot(\frac{1}{2}s-c)-\cot\frac{1}{2}s},$$

$$\text{vers sin } A = 2\cdot\frac{\cot b-\cot\frac{1}{2}s}{\cot(\frac{1}{2}s-c)-\cot\frac{1}{2}s} = 2\cdot\frac{\cot c-\cot\frac{1}{2}s}{\cot(\frac{1}{2}s-b)-\cot\frac{1}{2}s},$$

$$\sin\tfrac{1}{2}A = \sqrt{\frac{\cot b-\cot\frac{1}{2}s}{\cot(\frac{1}{2}s-c)-\cot\frac{1}{2}s}} = \sqrt{\frac{\cot c-\cot\frac{1}{2}s}{\cot(\frac{1}{2}s-b)-\cot\frac{1}{2}s}},$$

$$\cos\tfrac{1}{2}A = \sqrt{\frac{\cot(\frac{1}{2}s-b)-\cot c}{\cot(\frac{1}{2}s-b)-\cot\frac{1}{2}s}} = \sqrt{\frac{\cot(\frac{1}{2}s-c)-\cot b}{\cot(\frac{1}{2}s-c)-\cot\frac{1}{2}s}},$$

$$\tan\tfrac{1}{2}A = \sqrt{\frac{\cot b-\cot\frac{1}{2}s}{\cot(\frac{1}{2}s-c)-\cot b}} = \sqrt{\frac{\cot c-\cot\frac{1}{2}s}{\cot(\frac{1}{2}s-b)-\cot c}},$$

where A is one of the angles of a spherical triangle, b, c the adjacent sides, and s the sum of the sides.

On the Spectrum of Brorsen's Comet, observed at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

Brorsen's Comet was examined with the half-prism spectroscope mounted on the Great Equatoreal on April 17, and subsequent evenings whenever the state of the sky allowed. The dispersion used was that of one compound "half-prism," equivalent to four flint prisms of 60° (20° from A to H) with a power of 12 on the viewing telescope.

The spectrum consists of the three usual cometary bands, corresponding to the three principal bands of the second spectrum of carbon, and does not present the anomalous appearance found by Dr. Huggins in 1868. The bands were compared on several evenings with those shown by a vacuum tube containing vapour of alcohol at a pressure of 1·2 m.m., and the coincidence appeared sensibly perfect.

The position of the brightest comet-band (in the green) was measured with Hilger's bright line micrometer on two evenings, April 19 and 28, by Mr. Maunder; on other occasions it was compared with the corresponding carbon-band indirectly by means of a movable bar in the eyepiece, 30 tenth-metres broad. The following are the results of the micrometer readings for the less refrangible edge of the comet-band referred to the centre of the brightest portion of the carbon-band, which (with a narrow slit) is less than 5 tenth-metres broad:—

1879.	Comet-band.	Wave-length inferred.	Width of slit. in.
April 19	0·5 tenth-metres to blue	5190	0·009 = 16 tenth-metres.
28	4·5 „ to red	5191	0·013 = 24 „

The wave-length of the less refrangible edge of the carbon-band (alcohol vapour in a vacuum tube) has been taken at 5198·3 tenth-metres. As it was not found practicable to use a narrower slit, there is probably an uncertainty of several tenth-metres in the position of the comet-band, but it appears from these observations that it coincides approximately with the band in the second spectrum of carbon (vacuum tube) at 5198, and not with that in the first spectrum (blue flame of Bunsen burner) at 5165. On April 17 several comparisons were made by Mr. Christie, by bringing up a movable bar from the blue end of the spectrum so as just not to hide the bright edge of the comet-band, and in every case the coincidence of the less refrangible edges of the comet- and alcohol-bands appeared sensibly perfect. In these observations the slit was of such a width that the bright line, with which the alcohol-band commences, had a breadth of about 30 tenth-metres. The principal comet-band extended about ⅔ of the way towards F, to about wave-length 5,000, its blue end appearing to coincide approximately with a faint band of alcohol.

The second comet-band in the yellow was measured on April 28 by Mr. Maunder, and its red edge was found to be 2·4 tenth-metres to the red of the middle of the brightest part of the alcohol-band at 5610. The slit, however, was very wide, viz. $0^{in}\cdot033$, corresponding to 65 tenth-metres. This measure would place the red edge of the comet-band at 5580, whilst the band in the first spectrum of carbon is at 5635. The more refrangible end of the yellow band appeared to coincide with a well-marked band in the alcohol spectrum. The third comet-band was very faint; it appeared to be in the

neighbourhood of the blue band of alcohol at 4835. The relative brightness of the three bands was estimated thus: Green, 10; Yellow, 3; Blue, ½.

The comet has now decreased considerably in brightness, and its spectrum has become extremely faint. Unfortunately no observations were practicable before April 17, as the Great Equatoreal was in the workmen's hands for alterations to adapt it to more convenient use with the spectroscope.

The observations were made by Mr. Christie and Mr. Maunder.

Royal Observatory, Greenwich,
1879, *May* 9.

Observations of Brorsen's Comet. By Lord Lindsay.

1879, April 12, at $12^h\ 9^m$ S.M.T., the comet was well seen between clouds. It had a raylike tail, which could be traced for about 25′ from the highly condensed nucleus. The coma was obviously elongated at right angles to the direction of the tail, its greatest diameter being about 5′. Clouds prevented further observations.

April 16, $10^h\ 30^m$ S.M.T., tail 10′ long, in position 57°·8 by six measures with powers 122 and 229. No structure could be detected in the nucleus with powers 229 or 312.

April 17, $12^h\ 56^m$ S.M.T., tail 13′ long, in position 51°·9 from three measures with power 122.

The spectrum was observed on April 16, May 2 and 3.

It consisted of three broad bands, the brightest parts of which had the following wave-lengths:—

	m.m.m.
No. 1	547·6
2	515·6
3	469·6

Nos. 2 and 3 were sharply bounded on the less refrangible side, fading off gradually towards the violet. No. 1 was very ill-defined on both sides, and, being without any definite brighter part, its wave-length is very uncertain. Observers, Ralph Copeland and J. G. Lohse.

Dunecht, 1879, *May* 7.

Observations of Brorsen's Comet. By J. Tebbutt, Esq.

On Saturday evening, February 22, at 8 o'clock, I detected a faint nebulous object close to the position assigned to Brorsen's Comet in the Ephemeris of Dr. Schulze in the *Astronomische Nachrichten*, No. 2220. It presented the appearance of

an elliptic nebula, the major axis being nearly coincident with a parallel of declination. Unfortunately the object, was only visible in the fading twilight for about ten minutes, it having disappeared behind the walls of the new Observatory now in course of erection. I saw it again for about an equal interval last evening, and succeeded in obtaining a very imperfect ring comparison with a star of the 5½ mag. identified as B.A.C. 200 or 17 *Ceti*. The star crossed the northern side of the ring, while the comet, unfortunately, only grazed the exterior southern edge. From this rough observation the comet appeared, at $8^h\ 2^m$ local mean time, to be about $3^m{\cdot}3$ east and 11 south of the star. I had not time to repeat the observation. During the interval between the 22nd and 23rd the comet had moved considerably to the east and north.

I trust to be able to send some useful observations of this body. In the meantime I forward this hurried note, as the Torres Straits mail closes to-morrow at Sydney.

Observatory, Windsor, N.S.W.,
1879, *Feb.* 24.

Observations of Brorsen's Comet. By H. C. Russell, Esq.

By aid of Dr. Schulze's Ephemeris, *Astronomische Nachrichten*, No. 2220, I found the comet on February 24, but it was cloudy, and I could not get a comparison with a star before the clouds hid the comet. The 25th was cloudy; but on the 26th I found the comet as soon as it was dark enough to see it, $7^h\ 40^m$ P.M. It was very faint, about 3 seconds (time) in diameter, with a little central condensation, but no nucleus.

The mean of seven comparisons with B.A.C. 248 gave the following result:—

		h m s	
S.M.T.		7 50	
Comet following star		1 46·71	
		′ ″	
Comet south of star		10 55·19	Not corrected for refraction.
		h m s	
Position therefore of comet	R.A.	0 49 57·64	
		° ′ ″	
	N.P.D.	99 34 45·97	

It has been cloudy every night since until to-night. I saw the comet and obtained a comparison with Weisse No. 223, but it was very difficult, owing to moonlight.

	h m s	
Star and comet, same R.A. at	8 15	S.M.T.
	′ ″	
Comet south of star	5 21·57	

Sydney Observatory,
1879, *March* 6.

Note on Gruithuisen's Lunar Crater "Schroeter."

By John Birmingham, Esq.

(*Communicated by W. H. M. Christie.*)

In view of the discussions about Dr. Klein's lunar crater, it strikes me that an observation of Gruithuisen's *Schroeter* which I made on March 29, 1871, may be worth notice. On that night, with the terminator on *Eratosthenes* and *Plato*, I saw that the formation ended on the south with two large craters joined together in a nearly meridional line. The southern crater at the extreme end was deep, and the other, inside, which I will call No. 2, was very shallow, but rather wider than the former. From No. 2 a long ridge or bank ran towards the north, and from the other crater another bank went past No. 2 on the west, and advanced in a direction rather west of north, forming a small angle with the other ridge. These two banks were connected by four transverse banks, two of which—the more northerly—extended beyond the longitudinal bank to the west. Neither this latter bank nor crater No. 2 was represented by Lohrmann, nor in Dr. Schmidt's map do I find a trace of either one or the other. From the very peculiar and striking character of the formation, and its association with the phantasies of Gruithuisen, it might naturally be considered to have strong attractions for an observer like Dr. Schmidt, and such appears to have really been the case, for in his descriptive letterpress accompanying the map, he declares that Beer and Maedler* succeeded in representing the object better than himself; and this strikes me as signifying close and repeated observations on the part of Dr. Schmidt. I have not seen Beer and Maedler's work referred to, and cannot say whether the bank and crater in question are to be found there or not; but in any case I should scarcely believe those features to be new, and should be more inclined to regard them as affording striking examples of the oversights of even the best observers. I say this, however, without offering any opinion respecting Dr. Klein's crater, or any theory which it might be considered to support.

* In their work relating to the physical condition of the heavenly bodies, published at Weimar in 1841.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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Professor CAYLEY, F.R.S., Vice-President, in the Chair.

The Rev. Daniel Ace, D.D., Laughton Vicarage, Gainsborough;

was balloted for and duly elected a Fellow of the Society.

The Approaching Opposition of Mars. By N. E. Green, Esq.

The Opposition of this planet will occur before the next meeting of the Society. I desire to call the attention of the Fellows to the circumstance that this will be the most favourable opportunity for many years for examining the details of the equatoreal continents.

A careful search should be made for the remarkable dark canals figured by Professor Schiaparelli, which are represented by him as connected with the bays of the sea of Maraldi and the strait of Herschel, especially with the two points of Dawes' Forked Bay.

The northern declination of *Mars* will compensate in great measure for the reduction in its diameter when compared with that of the last opposition, and every use should be made of this occasion for the re-examination of previous drawings.

Extract of a Letter from E. J. Stone, Esq., to the Astronomer Royal, dated Royal Observatory, Cape of Good Hope, 1879, May 5.

I am thankful to say that my Catalogue is at last finished. The last six hours of R.A. will be sent home by the next mail. It will contain 12,450 stars. The work has been most carefully prepared and examined; in fact, I have devoted myself entirely to the work, and have left no stone unturned to make it as good as possible. It must be the chief work of my life. I take with

me my ledgers to read the copy through press, but all the original books of observation and books of reduction will be left here. I shall not require them, for I have read and re-read all the parts not printed I shall also take with me the ledgers containing the unprinted observations incorporated in the Catalogue, 1877, 1878, and part of 1879. Mr. Gill will therefore be entirely clear from all responsibility for my work. I have pushed on the work here to such an extent that it would have taken more than four years to have printed the observations now completed for press, at the highest pressure ever attained at the Cape. Of course the first thing is to print the Catalogue, which contains all the results. Probably it may afterwards be desirable to print at least the table of instrumental corrections, and the separate mean results for 1877, 1878, and 1879; but I should not think it would be worth the expense of printing the annual Catalogues for these years. In this way expense would be greatly reduced, and everything needful could be given to astronomers. The work as sent home is complete, except that all the constellations have not been put in.

On the Value of the Solar Parallax derived from Observations of Mars made at Ascension Island during the Opposition of 1877.

By D. Gill, Esq.

It is well known to the Fellows of the Society that the special object of the Ascension Expedition was to determine the solar parallax from observations of the diurnal parallax of *Mars*. The reductions are now so far completed that I can communicate the resulting parallax to the Society; and I have thought it better to do so without further delay, as some time must necessarily elapse before the full details can appear in the *Memoirs*.

The general plan of observation and treatment of the reductions has been described in the *Monthly Notices* for November 1878. According to that method, the places of the stars of comparison are regarded as absolutely known.

It was found, however, that the mutual distances of the comparison stars computed from the coordinates determined by meridian observations differed systematically from the same distances measured with the Heliometer according as the fainter star preceded or followed the brighter star. When the brighter star was preceding the computed distance always exceeded the measured distance, and *vice versâ*. In other words (regarding a $4\frac{1}{2}$-mag. star as the mean magnitude of clock stars), the R.A. of the fainter stars appeared to be too great.

In the *Monthly Notices* for December 1878 it was shown that there appeared to be a systematic difference of personal error depending on magnitude, between observations by Eye and Ear

and observations recorded by Chronograph. Separating the results derived from Eye and Ear observations from those derived from chronographic registration, it was found that in the mean the former agreed perfectly with the Heliometer results, whilst the latter showed a still larger discordance, depending on magnitude, nearly proportional to the magnitude, and amounting to nearly 0″·25 of arc per magnitude, for stars from 4·5 to 8·5 magnitude.

Thanks to the energy and kindness of many astronomers, these results have received much independent confirmation.

The most satisfactory method yet followed appears to be to observe the transit of a star over half the wires with the full aperture, then interpose a wire screen and observe the star over the remaining wires; the difference of results, when reduced to the middle wire, is due to Personality. To eliminate error in the wire intervals and possible change of collimation, the operation is repeated in the reverse order—the screen being used with the first wires, the free aperture with the last. The faint diffraction lines formed by the screen are entirely invisible in an illuminated field; the star disk of a 6th-mag. star reduced thus to 8th mag. by a wire screen, is quite indistinguishable from an 8th-mag. star observed in the ordinary way.*

Experiments have been made in this way by Dr. Becker at Berlin, by Professor Lewis Bass at the Dudley Observatory, Albany, U.S., and at Leiden by Professor Bukhuyzen's Assistants, and, I believe, also at other Observatories.

The results, so far as I have received them, entirely confirm the results of the Heliometer observations, and show that the R.A. of faint stars observed by the chronographic method is always too great.

I think it is desirable, before publishing the Memoir on the Parallax in full detail, to wait for the results of observations already made or in progress in connection with this investigation of the effect of magnitude on the R.A.

I have, however, satisfied myself that no alterations which are possible in the adopted places of the comparison stars will produce any sensible effect on the resulting parallax; because, not only must these be very small, but they will be nearly equally distributed amongst morning and evening observations.

I do not, therefore, on that account further delay communication of the parallax obtained. The method of reduction is quite similar with that employed in my preliminary paper (*Monthly Notices* for November 1878), except that two additional terms have been introduced in order to examine the influence of errors in the assumed refraction east and west of the meridian.

If r denotes the tabular refraction for any particular distance,

* I had recently the opportunity to test the experiment myself at Leiden, and I was entirely satisfied as to this point.

then the true refraction, if the observation is made east of the meridian, is supposed to be

$$r+\frac{r}{100}m;$$

and, if the observation is made west of the meridian, is supposed to be

$$r+\frac{r}{100}m'.$$

These terms m and m' are carried throughout the whole computation, so that the final coefficients of m and m' in the result express the effect on the parallax of an error of *one per cent.* in the tabular constant of refraction both east and west of the meridian.

As stated in my preliminary paper, it was obvious, from the arrangement of the order of observation and the positions of the comparison stars, that the final effect of errors in refraction must be insensible, and so the result of rigid computation has proved.

The actual coefficients of m and m', in the final result are

$$-0''.0002\,m \qquad\qquad -0''.0002\,m';$$

so that an error of $2\frac{1}{2}$ per cent. in the refraction tables would be required to change the resulting parallax $\pm 0''.001$.

It is therefore impossible to conceive any systematic error due to refraction in its ordinary sense. The Astronomer Royal has, however, called attention to a possible source of error of great importance due to atmospheric dispersion. At considerable altitudes a star is not a disk, but is elongated into a short vertical spectrum by atmospheric dispersion, and we do not see the upper and lower limbs of a planet, but their spectra. It is very easy to conceive that the effect of this may be to shift the apparent place of the planet upwards or downwards, and thus an error in the same sense as parallax may be produced.

Such an effect, however, will vary as the tangent of the zenith distance. Therefore, if we divide the observations of each morning and evening into two groups—observations at greater and smaller zenith distance—we may, by comparing the parallax resulting from the observations at smaller zenith distances with that from observations at greater zenith distances, ascertain whether the effect of atmospheric dispersion affects the parallax in a sensible degree.

Such an investigation accordingly was carried out. The small difference of the two resulting parallaxes ($0''.006$) appears to show that the error due to atmospheric dispersion is insensible.

The observations before and after Opposition were also independently reduced, and the results agree within limits of probable error.

Finally, in order to test whether possible error in the star

places could produce sensible error in the result, a final reduction was made in which only those observations were employed where the same stars were systematically employed the same evening and morning. The result is within the limits of probable error.

The assumed solar parallax was 8″·80.

The following are the direct results, where n is the number of $\frac{1}{100}$ parts which the assumed parallax has to be increased, according to the notation of the Astronomer Royal :—

	Value of n	Weight	Corresponding Solar Hor. Par.
			″
From all observations combined	−0·189	5·20	8·783
„ observations at greater ZD's	−0·164	3·03	8·786
„ „ at smaller ZD's	−0·223	2·17	8·780
„ „ before opposition	−0·098	3·06	8·791
„ „ after „	−0·317	2·14	8·772
„ symmetrical observations only	−0·430	2·12	8·762

The weights given for the various results have been rigidly computed. The probable error corresponding to weight 1 is equivalent to the probable error of a single complete measure of distance.

If then

r = the probable error of 1 observation of distance,

w = the weight of any of the above values of n,

then the probable error of the resulting parallax will be

$$\frac{8·8}{100} \times \frac{r}{\sqrt{w}}.$$

Until all means have been exhausted to reduce the errors of the star places, it is is not desirable to compute rigidly the final probable error. But if we adopt even so extreme a probable error as ±0″·40 for the single observation of distance (and there is good evidence that it is less than this), the resulting parallax from all the observations is

$$8″·78 \pm 0″·015.$$

It is interesting to remark that this result agrees with that derived from the combination of Struve's constant of aberration with Cornu's determination of the velocity of light.

S.S. "Taymouth Castle," Madeira.

so that we shall fall into no very great error if we take

h	m	s
1	5	21·21

for the difference of longitude between Greenwich and Vienna.

The reduction of the point of observation to the old University Observatory of Vienna is $+10^{s}\cdot52$. For this latter point, therefore, the difference of longitude with respect to Greenwich amounts to $1^{h}\ 5^{m}\ 31^{s}\cdot73$, which agrees very well with the old (*Nautical Almanac*) value; i.e. $1^{h}\ 5^{m}\ 31^{s}\cdot9$.* In general it would appear that the old longitudes, obtained without telegraphic operations, are not so bad as is commonly supposed.

On the Coincidence of the Bright Lines of the Oxygen Spectrum with Bright Lines in the Solar Spectrum. By Henry Draper, Esq., M.D.

I intend in this paper to speak of the steps that led to the discovery of oxygen in the Sun, to describe very briefly some of the successive improvements of the electrical and optical apparatus employed, and finally to discuss the earlier results and to show their subsequent confirmation.

In 1857, after the meeting of the British Association at Dublin, some of the members, by the kindness of the Earl of Rosse, were invited to visit the 6-foot Reflector at Birr Castle. In this way I enjoyed the advantage of seeing the methods by which that great instrument had been produced, and, on returning to America in 1858, it prompted me to begin the construction of a metallic speculum of 15½ inches aperture. Soon after, by the advice of Sir John Herschel, who had early information of Foucault's work in Paris, the metal was abandoned in favour of silvered glass, and several mirrors were ground and polished. The telescope was constructed especially for photography, and good results were obtained in 1863, culminating in the production of a photograph of the Moon 50 inches in diameter. These were published in the *Smithsonian Contributions to Science* for the succeeding year. The success procured with this instrument prepared the way for making a silvered glass Equatoreal of 28 inches aperture, which was ready for use in 1871, though it has been much modified since. It was obvious that increased light-

* *Note by Mr. Lynn.*—Until 1872 the *Nautical Almanac* has $1^{h}\ 5^{m}\ 31^{s}\cdot9$; from 1873, $1^{h}\ 5^{m}\ 31^{s}\cdot3$, adopted from the *Berliner Astronomisches Jahrbuch* for 1870. The former value was adopted from an investigation by Professor Littrow in 1824 (*Ast. Nach.* vol. iii. p. 64), based on observations of solar eclipses and occultations made about the end of the last century. It is worthy of notice that the result of the mean of six direct comparisons between Greenwich and Vienna there given (from two eclipses of the Sun in 1787 and 1788 and four occultations of stars in *Taurus* and *Gemini* in 1786, 1788, 1791, and 1792) is $1^{h}\ 5^{m}\ 31^{s}\cdot78$, closely agreeing with that of Dr. Oppolzer above.

collecting power and precise equatoreal movements were necessary for the modern applications of physics to astronomy. More recently still there has been attached to the same equatoreal stand an achromatic telescope of 12 inches aperture made by Alvan Clark & Sons, this being particularly intended for solar spectroscopic work.

Soon after the 28-inch Reflector was turned to stellar and planetary photographic spectroscopy, it became evident that the results obtained required for their interpretation photographs of metallic and non-metallic spectra, so that comparisons might be instituted leading to precise knowledge of the elements producing lines at the more refrangible end of the spectrum. This led to a division of the work into two parts, one for the Observatory in the country in the warmer half of the year, the other for my town Laboratory during the winter. It was in the latter that most of the oxygen work has been done, and consequently the engine, the Gramme machine, the induction coil, and the large spectroscope are generally there.

My first photographs of metallic spectra were taken with such apparatus as happened to be at hand, viz. a couple of Bunsen's batteries, an induction coil giving a spark of $\frac{1}{2}$ inch, and a Hofmann's direct-vision spectroscope. The length of the spectrum from G to H was about half an inch, but, though the dimensions were small, the promise was great. After some experiments, however, and after obtaining more powerful instrumental appliances, it seemed best, as able physicists were engaged on the metallic spectra, to turn attention more particularly to photographing the spectra of the non-metals. The exceedingly valuable researches of Dr. Huggins had brought the astronomical importance of nitrogen, carbon, and hydrogen into notice, and these accordingly were next the subject of experiment. Not long after, on examining a series of photographs of the fluted spectrum of nitrogen taken with juxtaposed solar spectra, the suspicion that there was a coincidence of some bright bands in the two spectra was suggested. On pursuing the subject with more and more powerful electrical and optical arrangements, the coincidence of bright lines of oxygen with bright lines in the solar spectrum was discovered.

The original apparatus, as has been said above, was on a very small scale, but it was soon replaced by a larger battery, a 2-inch induction coil, and a direct-vision prism of 1 inch aperture by Browning. The electrical part was made more and more powerful as the research proceeded, the 2-inch induction coil being succeeded by one of 6 inches, and that in turn by a Ruhmkorff coil capable of giving a spark of 17 inches. The battery was eventually superseded by a Gramme dynamo-electric machine which can produce a current powerful enough to give, between carbon points, a light equal to 500 standard candles. When this machine is properly applied to the 17-inch induction coil, it will readily give 1,000 10-inch sparks per

minute. These, being condensed by 14 Leyden jars, communicate an intense incandescence to air, and light enough is produced to permit of the use of a narrow slit, and of a collimator and telescope of long focus.

Since 1877, when the first publication of the discovery of oxygen in the Sun was made, still further improvements, especially in the optical parts, have been completed, so that I am now enabled to photograph the oxygen spectrum with four times the dispersion then employed. For the sake of clearness, it is best to give a brief description: 1st of the electrical part, and 2nd of the optical part.

The electrical part consists of the Gramme machine and its driving engine, the induction coil, the Leyden jars, and the terminal or spark compressor. An advantage the Gramme has over a battery is in the uniformity of the current it gives when an uniform rate of rotation of its bobbin is kept up. Of course this implies the use of a prime mover that is well regulated. The petroleum engine of one-and-a-half horse-power which I have employed is convenient and safe, and does this duty well. As to the Gramme itself, it is only needful to call attention to a modification of the interior connections. In one form the bobbin of wire which revolves between the magnets is double, so that the current produced may be divided into two. Under ordinary circumstances, where the machine is used to produce light, both sides of the bobbin send their currents through the electro-magnets. But if the whole current be sent through a quick-working break-circuit into an induction coil, the electro-magnets do not become sufficiently magnetised to produce any appreciable effect. It is expedient, therefore, to arrange the connections so that one-half of the bobbin gives a continuous current through the electro-magnets and keeps up the intensity of the magnetic field, and then the current from the other half of the bobbin may be used for exterior work, whether continuous or interrupted.

At first a Foucault mercurial interruptor was arranged to make and break the current passing into the primary circuit of the induction coil; but during the past year, by carrying the rate of rotation of the Gramme up to 1,000 per minute, the strength of the current has been so much increased that the mercury was driven violently out of the cup, and hence it was essential to arrange a mechanical break in which solid metal alone was used. This has been accomplished by fastening on the axis of the Gramme bobbin a wheel with an interrupted rim, which serves the purpose well.

As to the induction coil, it is only needful to say that it gives a good thick spark, which is limited to 12 inches, to avoid the risk of injuring the insulation. The Leyden jars are 14 in number, having altogether 7 square feet of coating on each surface.

The arrangement of the terminals from the Leyden jars to get the steadiest and brightest effect has offered great difficulties.

The condensed spark taken in the open air or in a gas under atmospheric pressure pursues, if unconfined, a zigzag course, and this is apt to produce a widening of the lines in the photographed spectrum. But, after many experiments, it turned out that the spark might be compressed between two plates of thick glass, or, better yet, between two plates of soapstone. If the interval between the plates was directed toward the slit of the spectroscope, the lateral flickering of the spark was prevented, and yet at the same time the spark was freely exposed to the slit without the intervention of glass or any substance on which the volatilised metal from the terminals could deposit. Very early in this research it had become apparent that Plücker's tubes could not be employed with electrical currents of more than a certain intensity, partly on account of the deposit that took place in the capillary portion, and partly because the terminals became so hot as to melt and crack the glass. Moreover, it was desirable to use one terminal of iron, so as to be sure that the spectrum of the gas was correctly adjusted to the solar spectrum, and this is impracticable with Plücker's tubes. An additional advantage arises from the soapstone plates, viz. the temperature of the small volume of air between the terminals is materially increased, and increased brightness results. I have tried the effect of warming the air by passing it through a coil of brass tube maintained at a bright red heat, but this does not seem to make any perceptible difference when the terminals are enclosed in the spark compressor.

Spark Compressor.

The optical part of my apparatus has undergone many modifications. At first a Hofmann direct-vision prism was combined with a lens of 6 inches focus; this was soon after replaced by a Browning direct-vision prism and a lens of 18 inches focus, the latter being arranged for conjugate foci, so that it was virtually as if collimating and observing lenses of 36 inches focus were employed. The final system, perfected this winter, consists of a collimator of 2 inches aperture and 26 inches focus, succeeded by two bisulphide of carbon prisms of 2 inches aperture and an observing or photographing lens of 6 feet 6 inches focal length. These prisms belong to Mr. Rutherfurd, and are the same he made for producing his celebrated solar prismatic spectrum. This gives a dispersion of about 8 inches between G and H, and enables me to get original negatives on a scale about half the size of Ångström's charts in the *Spectre Normal du Soleil*. When it is remembered that the light produced by the electric current in the spark compressor is scarcely equal to one standard candle, it will be realised that this great dispersion nearly attains the limit of present possibility. By comparison I have found, when the electric arc from this Gramme volatilises iron, the light is 60 times stronger than the most vivid incandescence of air that I have produced.

The slit of the spectroscope is about one inch long, and opposite the lower half is placed a right-angled prism which serves to bring in a beam of sunlight from a heliostat. We thus have the solar spectrum and the air spectrum upon the plate at the

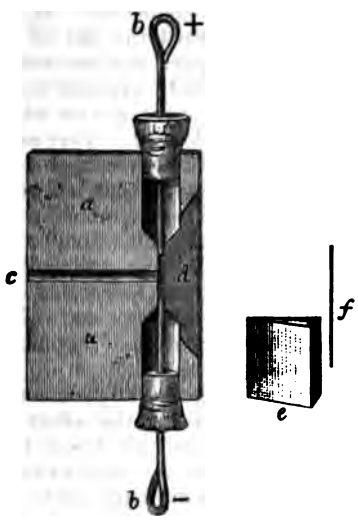


Fig. 1.
Section in plane of narrow opening.

Fig. 2.
Front view.

SPARK COMPRESSOR.

a a	Soapstone.	*d*	Narrow opening to spark.
b b	Terminals.	*e*	Right-angled prism.
c	Aperture for introducing gases.	*f*	Slit of spectroscope.

same time, so that the two spectra on the negative are, strictly speaking, simultaneously produced. Moreover, by the aid of a magnifier we can ascertain, just previous to an exposure, whether the adjustments are in the best order. It is not commonly known that, to obtain the last degree of exactness in coincidence between a solar and an air spectrum, many precautions are necessary; and for this reason it is desirable to have iron vapour present at one of the poles, so as to determine the reliability of the coincidence by comparing iron in the spark spectrum with iron in the Sun.

Diagram of Photographic Spectroscope.

Having thus alluded to some of the principal peculiarities of the apparatus constructed for this research, it is proper in the next place to point out the nature of the evidence afforded by the photographs of the presence of oxygen in the Sun. The first

photographs were on so small a scale that they did not even give rise to a suspicion of this fact, and it was not until 1876 that I felt sufficiently sure to make any publication. At this time the original negatives were about 2 inches long from G to H, and they bore an enlargement of three or four times quite well. The Albertype printed in 1877 in *Nature*, the *Comptes Rendus*, and the *American Journal of Science* was produced from such

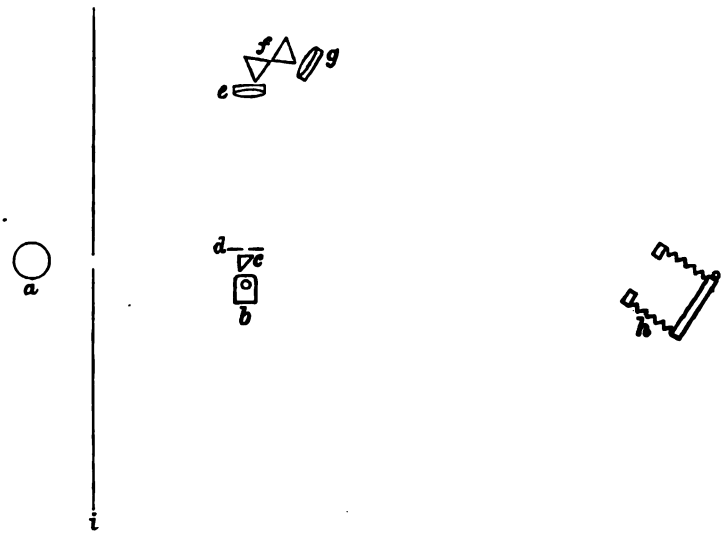


Fig. 3.

a Heliostat Mirror.	*f* Two bisulphide prisms.
b Spark compressor.	*g* Photographic objective.
c Right-angled prism.	*h* Camera.
d Slit.	*i* Window shutter.
e Collimator.	

an enlargement. Since that time, in order to meet the criticism that perhaps the dispersion was not sufficient to disclose the lack of coincidence if such existed, I have increased the dispersion four times and am thus enabled to make enlarged photographs on a scale about twice the size of Ångström's chart. Enlargements of the juxtaposed spectra of air and Sun on this scale are now presented for inspection.*

Of course an enlargement never does justice to the original from which it was produced; and, in order to study the matter faithfully, the negative must be examined carefully with a magnifier. Beside this, owing partly to the fact that the solar spectrum has suffered from absorptive influences, both in the Earth's atmosphere and in the solar atmosphere, the conditions under which the oxygen spectrum is seen when compared with the spark spectrum are modified. In fact, a critical study of

* These Enlargements were exhibited at the Meeting.—Ed.

the two spectra demands that each line of oxygen should be separately photographed with the corresponding region of the Sun's spectrum, so as to reproduce as nearly as possible the same conditions for each. As an instance of the modifications which may be caused by the solar atmosphere, the superposition of absorption lines on the bright lines of oxygen may be mentioned. If, as seems to be the case, the stratum giving the oxygen spectrum in the Sun lies deeper than the reversing layer in which iron exists, I see no reason why an iron absorption line, for instance, may not fall upon an oxygen bright band. In support of this supposition that oxygen is photospheric, it may be stated that, though I have examined the chromosphere on many occasions, I have not as yet seen the bright oxygen lines project beyond the apparent limb of the Sun as observed in the spectroscope, although several of the chromosphere lines catalogued by Young were readily visible. On consulting with Professor Young, he expressed the opinion that the oxygen groups near G did not appear as bright lines in the chromosphere, even under the exceptionally favourable circumstances he enjoyed at Sherman. For the purpose of continuing the study of this point, and also of examining small areas on the Sun, faculæ, spots, &c., Alvan Clark & Sons are constructing for me a special spectroscope, which can give the dispersion of twenty heavy flint prisms and can bear high magnifying power.

If it be conceded that there are bright lines in the spectrum of the solar disk, and this seems to be the opinion of several physicists, especially Lockyer, Cornu, and Hennessy, the question of their origin naturally attracts attention. It seems that there is great probability, from general chemical reasons, that a number of the non-metals may exist in the Sun. The obvious continuation of this research is in that direction. But the subject is surrounded by exceedingly great obstacles, arising principally from the difficulty of matching the conditions as to temperature, pressure, &c. found in the Sun. Anyone who has studied nitrogen, sulphur, or carbon, and has observed the manner in which the spectrum changes by variations of heat and pressure, will realise that it is well-nigh impossible to hit upon the exact conditions under which such bodies exist at the level of the photosphere. The fact that oxygen, within a certain range of variation, suffers less change than others of the non-metals has been the secret of its detection in the Sun. It appears to have a greater stability of constitution, though Schuster has shown that its spectrum may be made to vary. I have already begun an extended series of experiments on the non-metals; but the results exhibit such confusion that their bearing cannot at present be distinctly seen. In the case of nitrogen the broad bands between G and H exhibit, under the most intense incandescence, a tendency to condense into narrow bands or lines, and indeed there are some sharp lines of nitrogen in the photographs now presented.

It does not follow, therefore, that the bright bands of oxygen are necessarily the brightest parts of the solar spectrum. Other substances may produce lines or bands of greater brilliancy.

There is also another cause for a difference of appearance in a bright-line spectrum produced in a laboratory and bright lines in the Sun. While the edges of a band in the spark spectrum may be nebulous or shaded off, the corresponding band in the solar spectrum may have its edges sharpened by the action of adjacent dark lines due to one or another of the metallic substances in the Sun.

On the whole, it does not seem improper for me to take the ground that, having shown by photographs that the bright lines of the oxygen spark spectrum all fall opposite bright portions of the solar spectrum, I have established the probability of the existence of oxygen in the Sun. Causes that can modify in some measure the character of the bright bands of the solar spectrum obviously exist in the Sun, and these, it may be inferred, exert influence enough to account for such minor differences as may be detected.

In closing, it may be well to give some idea of the amount of labour and time this research has already consumed, and this cannot be better done than by a statement of the production of electrical action that has been necessary. Each photograph demands an exposure of 15 minutes, and, with preparation and development, at least half an hour is needed. The making of a photograph, exclusive of intermediate trials, requires, therefore, about 30,000 10-inch sparks, that is 30,000 revolutions of the bobbin of the Gramme machine. In the last three years the Gramme has made 20 millions of revolutions. The petroleum engine only consumes a couple of drops of oil at each stroke, and yet it has used up about 150 gallons. Each drop of oil produces two or three 10-inch sparks. It must also be borne in mind that comparison spectra can only be made when the Sun is shining, and clouds therefore are a fertile source of loss of time.

London, June 10, 1879.

On the Photographic Semi-diameter of the Moon.

By Professor C. Pritchard.

In the course of measuring the Lunar Photographs which have been obtained in the Oxford University Observatory by means of the De La Rue Reflector of 13 inches aperture, it occurred to me, for the purposes simply of acquiring confidence or otherwise in the laborious processes which have been undertaken, to compare the mean semi-diameter of the Moon thereby obtained with the mean semi-diameter adopted in the *Nautical Almanac*; and also to compare the photographic results with

similar results deduced from Wichmann's measures made with the Königsberg Heliometer in 1844.

The process of computation adopted at Oxford is very nearly the same as that proposed by Bessel and employed by Wichmann. Two small but well-defined craters were selected on the photographs, viz. *Ptolemy*, A, and *Triesnecker*, B; the latter being purposely chosen on account of its close proximity to the mean centre of the Moon's disk. A few measures have also been taken with *Hypatia*, B.

Distances from each of these craters were measured to six or seven points on the Moon's limb, arbitrarily but conveniently selected, and subtending known measured angles at the particular crater. These distances and angles were measured by means of Mr. De La Rue's engine, the scales and screws of which had been previously examined with scrupulous care. By methods well known to astronomers these data afford equations of condition for the determination of the photographic diameter of the Moon, as seen at the moment from the place of observation.

From each of these local and apparent semi-diameters, the mean geocentric diameter of the Moon has been computed by means of the formula

$$\Delta = \frac{\sin \varpi}{\sin p} \cdot D,$$

where D is the geocentric semi-diameter at the time of observation, p the corresponding parallax, Δ the geocentric semi-diameter at the mean distance, and ϖ the mean parallax. Twenty of these determinations thus obtained are tabulated below, and are printed in column II.

In column III. are printed the differences of the several values in column II. from the arithmetic mean (15′ 34″·175) given at the bottom of the column; the examination of these residuals by well-known methods shows that the probable error of the mean diameter of the Moon thus obtained is ±0″·069. The mean geocentric semi-diameter in use in the *Nautical Almanac* appears to be 15′ 34″·10; and the remarkably close agreement between these two results, thus obtained by methods entirely independent of each other, warrants, I think, confident reliance on the accuracy of the photographic method.

It is, however, to be carefully noticed that, while this preliminary and partial investigation may, it is hoped, attract the interest of the Society to a novel but most careful application of photography, nothing beyond this general accuracy of the method is here sought to be established.

With regard to Wichmann's measures, it may be remarked that the instrument he used was the Königsberg Heliometer, and that he reduced his resulting measures by nearly the same methods as those adopted at Oxford. In column IV. I have given the resulting differences between the local semi-diameters

thus computed and the corresponding ones given in the *Berliner Jahrbuch*, in which Ephemeris Burckhardt's values are adopted. The probable error of the mean of twenty consecutive semi-diameters is about $\pm 0''.13$, being nearly double that which attaches to the photographic results.

From a remark found in Wichmann's most able paper, it appears that the mean value of the Moon's semi-diameter as obtained from the whole series of his measures, fifty in number, differs from that obtained from his twenty consecutive measures, by a quantity far too inconsiderable to be taken into account.

The Heliometer having hitherto been considered the most accurate instrument for the measurement of comparatively small distances, it seems desirable to place the results of the heliometric and the photographic methods in juxtaposition.

Column I. Observed Crater.	Column II. Moon's Mean semi-diameter.		Column III. Difference from Arithmetic Mean (15′ 34″.175).	Column IV. *Berliner Jahrbuch* semi-diameter 1844 − Heliometer measure.
	′	″	″	″
Triesnecker, B.	15	34·295	0·120	−0·164
Ptolemy, A.	15	33·931	0·244	−0·907
Triesnecker, B.	15	34·820	0·645	+0·013
	15	34·315	0·140	−0·854
	15	34·568	0·393	−1·132
Ptolemy, A.	15	34·150	0·025	−1·457
Triesnecker, B.	15	33·457	0·718	−1·196
	15	34·031	0·144	−0·511
Ptolemy, A.	15	34·591	0·416	−0·453
Triesnecker, B.	15	34·380	0·205	−1·454
Ptolemy, A.	15	34·801	0·626	−0·878
	15	34·787	0·612	−3·332
	15	33·884	0·291	−2·475
Hypatia, B.	15	34·262	0·087	−1·080
	15	33·590	0·585	−0·694
	15	34·178	0·003	−0·242
	15	34·271	0·096	−0·536
	15	33·280	0·895	−2·294
	15	33·469	0·706	−1·849
Ptolemy, A.	15	34·447	0·272	−0·252

The mean of the above photographic semi-diameters is 15′ 34″.175, with a probable error of $\pm 0''.069$. The comparison of columns III. and IV. will furnish an idea of the results which may be expected from the two methods of measurement. Further details will be given in the next fasciculus of the Oxford University Observatory, to be published at an early date in next year.

M M

Spectroscopic Observations of the Motion of Stars in the line of Sight, made at the Temple Observatory, Rugby.

By Geo. M. Seabroke, Esq.

For some time past I have been engaged, whenever time would allow, in the spectroscopic estimation of the motion of stars towards and away from our system. The results I have obtained are very inconclusive; but I think it desirable, for the following reasons, that I should bring them before the notice of the Society without further delay. First, they are all *bonâ fide* attempts at correct measures and were carefully made, and a perusal of them, together with those of other observers, will show the wide difference of the results on the same star; and will prevent hasty conclusions based on the assumed accuracy of such measures, while they still show sufficient accordance to give some hope that, with increased instrumental power, accurate results may be obtained. Secondly, this paper is a contribution to the knowledge of the best methods of making delicate observations of this kind, and an account of early attempts shows what to avoid as well as what to do.

The instrument I have used in this research is a Newtonian Reflector of $12\frac{1}{8}$ inches aperture and 6 feet 6 inches focal length, mounted equatoreally, and a Barlow lens is carried in the eye-piece, having an effect equivalent to doubling the focal length of the mirror. The spectroscope used has a collimating lens of $\frac{3}{4}$ inch diameter and 5 inches focal length, and the prisms are so arranged that the rays first traverse the lower part and then are reflected back through the upper part of them to the observing telescope. In my early measures a number equivalent to 4 of 60° were used, and a power of 15 on the observing telescope, but I have lately used 5 and 6 prisms (1 or 2 half-prisms and 2 whole ones of 60° twice over) and a power of 25.

I have tried many methods of comparison. I will enumerate the chief of them. First, the comparison light from the hydrogen vacuum tube was, by reflection, mixed with the rays from the star on the slit of the spectroscope; secondly, the comparison light was reflected on the slit by the side of the star, so that the spectra were viewed side by side. Both these methods rendered the detection of any noncoincidence easy; but the dark line of the spectrum of the star was often put out in the first method, and in the second the measurement of the displacement was difficult and uncertain when made with a bright-wire-micrometer both fixed in the eye-piece, and with the wires reflected by the surface of the last prism, so that the images only were seen. This was probably owing to the lines whose distances apart were to be measured not being side by side, and also being slightly curved.

I have therefore adopted the following method. The vacuum tube is carried by two wooden clips, which also embrace at their other extremities a glass rod fixed to the spectroscope in such a

position that the tube can be swung at pleasure in front of the slit or below the level of the same; the spectrum of the star and that of the tube can then be viewed alternately by a slight motion of the latter. The displacement of the line is measured as follows:—A brass tube 8 inches long carries a collimating lens at one end, and in its focus at the other is a piece of tinfoil, with a minute hole in it, moved by a micrometer screw; the tube is so fixed that the spot of light from the tinfoil is reflected from one of the surfaces of the last prism, or the last but one, and is focussed in the eye-piece with the spectrum viewed. In the case of the first prism of the train being a half one with its surface last passed by the rays normal to the axis of the observing telescope, the last surface of the next one must be used for the purpose of reflecting the micrometer spot; and since it has then to pass through one half-prism to the observing telescope, it would be drawn out into a spectrum, if it were not illuminated by a monochromatic or nearly monochromatic light. The hole in the tinfoil is therefore illuminated by a small swing spirit lamp, with a coil of platinum wire holding common salt over the wick. The spectra of the star and tube are alternately thrown into the field, and the spot of light made to coincide with each in its turn, and the readings of the screw are noted; by subtraction the value of the displacement in terms of the divisions of the screw is then obtained. The value of the latter in wave-lengths is obtained by measuring the distance between the F-line and any other line of known position near it in the solar spectra, or by measurement of the distance between the magnesium lines produced by the electric spark. In my apparatus about 4 divisions of the screw correspond to an alteration of one tenth-metre in wave-length. The vacuum tube is placed with its length at right angles to the slit, the latter of which is placed so that the star would traverse its length by its apparent diurnal motion. A cylindrical lens is used in front of the slit, for I find a considerable width of spectrum advantageous, and conducive to accuracy. The foregoing arrangements work well under existing conditions here, but they are no doubt capable of improvement.

I would remark that a less dispersive power, or its equivalent, than that I have been using, seems to me to be almost valueless for anything like reliable results, and in fact a greater instrumental power is the thing now to be obtained; and since the image of a star does not increase in size by increase of aperture and corresponding focal length of telescope, assuming perfection of workmanship we may make the image of the star on the slit intrinsically brighter almost without optical limit, while leaving the angle of the cone of rays constant; an increase of aperture will therefore render the spectrum brighter, or enable a greater dispersive power to be used with undiminished brightness of spectrum.

The subjoined list of measures explains itself sufficiently, except perhaps as to the sixth column, headed "Corrected motion

of Star," which contains the observed velocity of the star in miles per second, corrected for the value of the Earth's orbital motion, the sign + meaning that the star is receding from, and − approaching, our system.

Spectroscopic Observations of the Motion of Stars in the line of Sight made at the Temple Observatory, Rugby.

No.	Name of star.	No. of prisms.	Line compared.	No. of measures.	Corrected motion of star. Miles per sec.	Date 1800 +	Remarks.
1	γ Pegasi	5	F	2	+ 9·7	78·85	
2	Rigel	4	F	4	+29·3	77·15	Line badly defined.
3	γ Orionis	4	F	4	+41·58	77·05	
4	„	5	F	4	+18·1	79·16	
5	δ Orionis	5	F	3	+54·3	79·16	
6	ε Orionis	5	F	3	+13·3	79·16	
7	ζ Orionis	5	F	3	+16·5	79·16	
8	α Orionis	4	b_4	3	−96·9	77·15	Moonlight; doubtful.
9	„	4	F	2	+25·4	77·05	
10	„	4	F	est.	+24·9	77·09	
11	„	5	b_4	5	+32·9	79·17	
12	β Aurigæ	5	F	3	+ 0·6	79·17	Star line nebulous.
13	Sirius	4	F	2	+84·4	77·05	
14	Castor	6	F	2	+71·1	78·25	Star line hasy.
15	„	5	F	3	+14·8	79·17	
16	„	5	F	3	+23·7	79·25	
17	Pollux	4	F	2	+57·7	77·20	Very doubtful and faint.
18	„	5	F	1	−27·7	79·17	Very doubtful.
19	„	5	F	2	+26·6	79·25	
20	Procyon	4	F	5	−43·6	77·15	Moonlight.
21	„	4	F	4	+ 2·2	77·20	
22	„	4	F	2	+70·2	78·11	
23	„	4	F	3	+22·8	78·24	
24	„	6	F	2	+53·2	78·25	
25	„	5	F	3	−45·1	79·16	
26	„	5	F	4	+12·7	79·17	
27	„	5	F	3	+43·1	79·25	
28	η Leonis	6	F	3	+21·9	78·31	
29	Regulus	6	F	3	+57·3	78·25	
30	„	6	F	4	− 2·7	78·31	
31	„	6	F	5	+67·8	78·33	
32	„	5	F	5	+36·1	79·17	

No.	Name of star.	No. of prisms.	Line compared.	No. of measures.	Corrected motion of star. Miles per sec.	Date 1800 +	Remarks.
33	,,	5	F	3	+16·6	79·25	Line nebulous.
34	,,	5	F	2	+27·0	79·33	
35	,,	7	F	3	+35·1	79·33	
36	ε Ursæ Major.	5	F	3	−32·0	79·33	
37	δ Leonis	6	F	3	−59·5	78·33	
38	,,	5	F	3	+ 8·18	79·33	Line nebulous.
39	θ Leonis	6	F	4	−67·4	78·33	Very doubtful and faint.
40	,,	5	F	2	+44·6	79·33	Very faint and doubtful.
41	β Leonis	6	F	3	−73·5	78·25	Line very nebulous.
42	,,	6	F	5	+32·2	78·31	,, ,,
43	,,	6	F	3	+20·9	78·33	
44	,,	5	F	3	−41·8	79·33	
45	η Ursæ Major.	6	F	4	+ 7·8	78·46	
46	Arcturus	4	b_1	2	+53·7	77·45	
47	,,	6	b_1	1	−33·0	78·31	
48	,,	7	F	3	− 7·2	79·33	
49	ζ Boötis	6	F	2	−27·3	78·47	Doubtful and very faint.
50	α Cor. Bor.	6	F	3	+ 6·5	78·46	
51	,,	6	F	3	+22·3	78·47	
52	α Ophiuchi	6	F	3	−15·4	78·46	
53	Vega	4	F	4	−94·0	77·57	
54	,,	6	F	3	−14·5	78·47	Doubtful.
55	,,	6	F	6	−16·8	78·69	
56	,,	6	F	4	−41·0	78·71	
57	Altair	6	F	3	−44·0	78·69	
58	,,	6	F	4	+15·2	78·71	
59	,,	6	F	3	+26·0	78·72	
60	δ Cygni	6	F	4	−29·4	78·71	
61	,,	6	F	3	−57·8	78·72	
62	γ Cygni	6	F	3	−49·2	78·71	
63	,,	6	F	4	−43·0	78·78	Doubtful.
64	ε Cygni	6	F	2	+20·2	78·78	
65	α Cygni	6	F	3	−39·1	78·69	
66	,,	6	F	3	−56·9	78·71	
67	,,	6	F	4	+45·5	787·8	Very doubtful.
68	,,	5	F	4	−36·0	78·85	

Preliminary Paper on the Babylonian Astronomy.

By R. H. M. Bosanquet, Esq., and Professor A. H. Sayce.

The Calendar.

The progress of the decipherment of the Inscriptions of Assyria and Babylon has rendered it possible to develop with some certainty the fundamental principles of the Astronomy of those ancient nations. We are at present engaged in the study of the Babylonian Astronomy; and we desire to state that we have obtained certain results, and to give some indication of their nature.

The first question is, What was the nature of the Babylonian Calendar, and how did it depend on the motions of the heavenly bodies? Of this question we have been able to obtain a solution of an apparently complete nature. So far as we are aware, this calendar has never been discussed before; and it is as remarkable for its theoretical elegance as for its practical simplicity and historic interest. We do not say that every passage in the inscriptions harmonises with this calendar. Many of the inscriptions are very obscure; many are hopelessly corrupt copies of earlier ones; and many contain accounts of phenomena which are absolutely impossible on any hypothesis whatever. Under these circumstances the discussion of the evidence of the inscriptions is a matter requiring care and caution. But there is in our minds no doubt worth consideration that the calendar in question was substantially the calendar of those who wrote the inscriptions.

In the present paper we propose to quote a few of the principal passages on which the establishment of the calendar rests, and to give some account of it. Other subjects, such as the identification of stars, the measurement of longitude, and the treatment of the evidence generally, must await another opportunity.

First, we must premise that the inscriptions are written in at least two languages, Assyrian and Accadian; and everything has in consequence two names at least, though these are generally represented by the same character. The planets also frequently assume the names of stars in whose neighbourhood they were observed. For the present we will only take the case of the star *Icu* or *Dilgan*, which appears to have been the foundation of the calendar in question. It was called *Dilgan*, or "the messenger of light," in Accadian, and "Icu of Babylon" in Assyrian. The object of mentioning this is to explain how it is that the two names are used indifferently.

The following are the principal passages connecting this star with the beginning of the year.

In the reverse of the Catalogue, or Preface, of the *Illumi-*

nation of Bel (the great ancient astronomical work of Babylon), there occurs this passage, among the general enumeration of the phenomena and the astronomer's duties :—

"The appearance at the beginning of the year of the star *Icu*, ... one observes."

On the colophon of a tablet containing an enumeration of the stars of certain months there occurs, by way of contents, what is supposed to be the first line of the next tablet; it runs :—

"The star *Icu* in the month Nisan was seen."

The language of these two inscriptions is Semitic. They belong, however, to an ancient work compiled for Sargon of Agané about 1700 B.C.

These two passages prepare us to find that the definition of time by a star consists in its appearing; whereas it has commonly been supposed that the definition of time by a star consists in its disappearing behind the Sun.

The only kind of annual appearing that stars perform, for the purposes of those who watch all night, is their heliacal rising, or issuing forth from the region of the Sun before sunrise The frequent mention of the rising of stars confirms us in the opinion that the heliacal rising was the phenomenon by which they were chiefly classified. We were therefore prepared by these passages to find that the beginning of the year was regulated by the heliacal rising of some star.

The following passage now requires consideration: "When on the first day of the month Nisan the star of stars (or *Dilgan*) and the Moon are parallel, that year is normal. When on the third day of the month Nisan the star of stars and the Moon are parallel, that year is full" (i.e. has 13 months).

This inscription is in Accadian, the most ancient language of the inscriptions. It may be expected to belong to a time earlier than 2000 B.C.

On considering this inscription from the point of view of modern astronomy, it becomes evident that we have here the key to the calendar, if we can only ascertain definitely that the months were lunar months; so that the beginning of the year could be defined by the Moon. As there is some difficulty about this point, it is necessary to consider it a little.

The following passage occurs in the Preface or Catalogue before mentioned :—

"12 months to each year, ($6 \times 60 =$) 360 days, in order are recorded by the hand . . . ."

If this was accurate, the months could not be lunar. But it is abundantly clear that they were lunar. The more recent inscriptions are the clearest on this point. They record cases of watching for the Moon at the end of the month.

The notices of eclipses throughout the inscriptions serve to confirm this conclusion. The eclipses of the Moon were generally observed about the 14th day, and those of the Sun from the

28th to the 30th. In some of the ancient astrological tablets there are collocations of observations of eclipses which present difficulties; but these still recur month after month on the same days, so that the lunar determination of the month is preserved throughout.

Further, the names of these months are substantially those of the lunar calendar of the Jews. It is therefore to be expected that the determination of the beginnings of the months will be found to be effected according to the custom of that calendar, which is by the observation of the first visible appearance of the new Moon.

(For a description of the Jewish custom *see* Disraeli's *Alroy*, Part x. ch. 1, "We are the watchers of the Moon, to tell the nation that the month begins.")

There is only one way of reconciling the calendar of lunar months with the statement as to the year of 360 days. The mean synodic lunation being about $29\frac{1}{2}^d$, the real length would often be 30^d. We must suppose that the reckoning up of the 12 sets of 30 days to the total of 360^d was the work of a commentator, or perhaps of an inaccurate writer or copyist. We have, in other parts of these tablets, examples of statements undoubtedly incorrect, which are to be ascribed to similar causes.

In order, however, to ascertain the possibility of working a lunar calendar according to the rule of 360 days, we have discussed the calendar thus resulting. And we find that undoubtedly a calendar of 360 days in the year can be worked approximately by lunar methods; but the rule on which the working of such a calendar would depend would be entirely different from that given in the inscriptions; while, the months being of 30 days, and not lunar months, the watchings for the new Moon and the eclipses would occur irregularly on all the different days of the month. And this would be contrary to what we find in the inscriptions.*

Assuming then that the months were lunar, and began with the first visible appearance of the new Moon, we proceed to deduce the nature of the calendar arising from the rule above quoted, viz.:—

"When on 1 Nisan the star of stars and the Moon are parallel, that year is normal. When on 3 Nisan the star of stars and the Moon are parallel, that year is full," i.e. has 13 months. We will first consider this rule independently of anything else,

* We may just mention that the lunar rule of the calendar of 360^d would depend on the fact that this period exceeds the lunar year of 12 lunations by the same amount, roughly, by which it falls short of the solar year; so that the lunar intercalary months would accumulate approximately at the same rate as those required to make up the solar year.

In fact

$$360^d = 12 \text{ mean lunations} + 5^d\cdot633$$
$$= 1 \text{ tropical year} - 5^d\cdot242$$

and afterwards take up its relation to the equinox, and the heliacal rising of the same star (*Dilgan* or *Icu*) at the beginning of the year.

We will consider this relation, "when the Moon is parallel to the star of stars," as defining a point on the ecliptic, which we will regard as the origin of longitude. And we will speak of longitude thus measured as "longitude from *Icu*." It will be positive when measured in the usual direction, from W. to E., and negative in the opposite direction.

Assume further, for small distances from *Icu*, that the Moon's mean distance from the Sun is 12° for each day from new Moon; that the Sun's daily motion is 1°; and the Moon's daily motion 13°.

The new Moon is said to be visible under the most favourable circumstances 18 hours after conjunction. The probable cases would therefore be included between the limits 18 and 42 hours after conjunction. We assume 30 hours for the mean time of visibility after conjunction.

In the mean normal year of the rule the Moon is, then, parallel to *Icu* on 1 Nisan, 30 hours after conjunction, or at a distance of 15° from the Sun. Hence,

Sun's longitude from *Icu* on 1 Nisan in the normal year is $-15°$.

In the "full year" of the rule the Moon is parallel to *Icu* on 3 Nisan, or in the mean $3\frac{1}{4}^{d}$ from the Sun. Hence,

Sun's longitude from *Icu* on 3 Nisan mean full year $= -39°$;

and, according to the rule, when the Sun is as much as this behind *Icu* on 3 Nisan an intercalary month is due at the end of the year.

The most remarkable thing about the rule so far is the way in which the Moon is used as a mere pointer in the sky, for measuring the distance from the Sun to a fixed point among the stars. For the comprehension of the actual working of this rule in each separate case, as above, nothing is needed but the very roughest knowledge of the Moon's mean motion for a few days. Without going any further, we see that the rule secures on the average an accurate sidereal year. For whenever the Sun, at the beginning of the year, has slipped more than a certain distance from a fixed point among the stars, an intercalary month is added to bring him up again.

We will now form the table of the succession of the years, and the introduction of the intercalary months, according to the approximate mean rule of lunations used in modern calendars.

According to this approximation, $1^{y} - 11^{d} = 12$ lunations. We can enumerate all the possible cases conveniently by supposing that the years succeed each other in the order thus determined, without return after the 19 years period. We can then always find some part of the table which shall approximately represent a given case.

As the lunar years are too short, let the Moon of 1 Nisan come x days too soon in the general case. Then x is a number

similar to the epact of modern calendars, and the Sun will be $x°$ behind his place in the normal year. Then,

			1 Nisan. °	3 Nisan. °
Normal Year	Longitude from * Icu*	Moon	0	26
,,	,, ,,	Sun	−15	−13
General Year	,, ,,	Sun	$-(15+x)$	$-(13+x)$
,,	,, ,,	Moon	$-x$	$26-x$

since the mean distances of the Sun and Moon on 1 and 3 Nisan are 15° and 39° respectively.

Table of the cases of the Babylonian Calendar, arranged in the order shown by a mean calendar Moon, without return after 19 years period.

	Sidereal years. y		Days over. d	Intercalary month. −x		Lunar years.	At the beginning of following year. Moon's longitude from *Ieu.* 3 Nisan $=26°-x°$. °	Intercalary Due at 7°.
Normal Year	1	−	11		=	1	15	
	2	−	22		=	2	4	I. D.
	3	−	33	+ 30	=	3	23	
	4	−	14		=	4	12	
	5	−	25		=	5	1	I. D.
	6	−	36	+ 30	=	6	20	
	7	−	17		=	7	9	
	8	−	28		=	8	−2	I. D.
	9	−	39	+ 30	=	9	17	
	10	−	20		=	10	6	I. D.
	11	−	31	+ 30	=	11	25	
	12	−	12		=	12	14	
	13	−	23		=	13	3	I. D.
	14	−	34	+ 30	=	14	22	
	15	−	15		=	15	11	
	16	−	26		=	16	0	I. D.
	17	−	37	+ 30	=	17	19	
	18	−	18		=	18	8	
	19	−	29		=	19	−3	I. D.
	20	−	40	+ 30	=	20	16	
	21	−	21		=	21	5	I. D.
	22	−	32	+ 30	=	22	24	
	23	−	13		=	23	13	
	24	−	24		=	24	2	I. D.
	25	−	35	+ 30	=	25	21	
	26	−	16		=	26	10	
	27	−	27		=	27	−1	I. D.
	28	−	38	+ 30	=	28	18	
	29	−	19		=	29	7	I. D.
	30	−	30	+ 30	=	30	26	

The rule for the intercalary month says, "when the Moon is parallel to *Icu* on the 3rd Nisan." But since the Moon moves through about 13° each day, we must admit half a day's journey, say 6° or 7°, to come within the rule.

And we must take 7° at least. For if we do not, the condition of the normal year can never recur; i.e. the parallelism to *Icu* on the 1st Nisan, or $x = 0$. We see from years 29 and 30 of the table that this happens when the longitude from *Icu* on 3 Nisan is 7° the year before, and the intercalary is then due. Of course it is not probable that the rule was worked to a single degree in this way; but for calculation we must draw the line somewhere, and we select 7° as the limit for the above reasons. It is remarkable that this rule of intercalaries leads to a series of values for x which are in all respects comparable with the epacts of the ecclesiastical calendars.

It will be seen that the values of x vary from 0 in the normal year to 29 in the 19th year of the series. That is to say, the Sun is always later than in the normal year, and may be as much as 29 days later. This is obviously a property of any calendar regulated by intercalary months; every true annual occurrence must be liable to an apparent oscillation of date amounting to the inside of a month.

So far we have said nothing about equinoxes; we have established the calendar, in accordance with the rule of the inscriptions, on a purely sidereal basis. We can now proceed to consider the probable position, with respect to the equinox, of our starting place—the point marked on the ecliptic as parallel to the star of stars.

There is reason to believe that the mean date of the equinox was not far from the beginning of Nisan. If we assume for the mean year No. 15 of the table, in which the Sun is 15° behind the normal position, or midway between its extreme positions, we have for the Sun's longitude from *Icu* on 1 Nisan, −30°. At the date of the establishment of the calendar, we may therefore expect to find the equinox about 30° behind the star *Icu*, or the star *Icu* about 30° in front of the equinox, with some considerable latitude either way. (For we cannot be sure that the mean position of the equinox would coincide with 1 Nisan, within 15 days or more either way.)

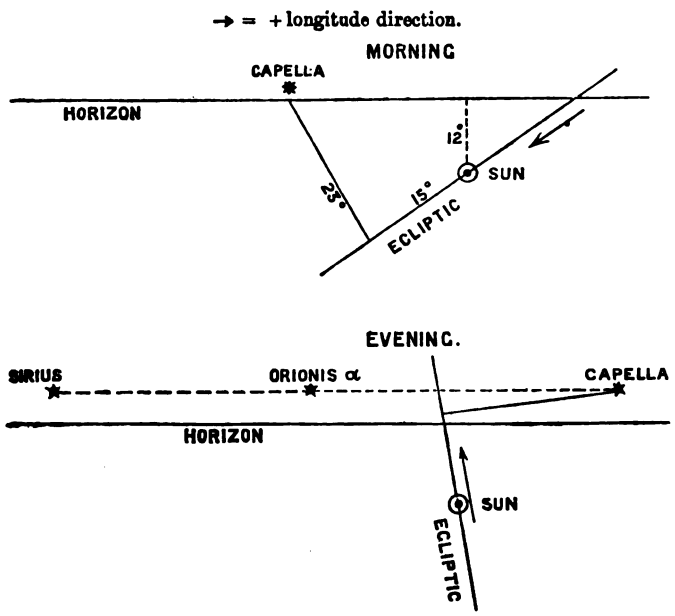
It is generally admitted that the establishment of this calendar is to be looked for about 2000 B.C. We select the number of 3,960 years, equivalent to 55° of precession, and seek for a star which was in longitude 30°±15° about 3,960 years ago; we seek especially for any star of the first magnitude which also satisfies the condition of rising heliacally about the time of the new year. There is no doubt about the result. The star *Capella* is the only star that satisfies these conditions; and numerous independent lines of evidence converge to identify it with *Icu*. It rose heliacally at the period in question before it set; its large north latitude, 22° 51′ 45″ (Delambre), or 23° nearly, throwing it up in the

morning, at the vernal equinox, when the ecliptic has its least inclination to the horizon.

The identification was effected by means of a celestial globe, on which the positions of the principal stars have been laid down for the period in question, referred to the equator and ecliptic of the globe as the equator and ecliptic of the period. But the following calculation exhibits the result as to the longitude:—

	°	′	″
Longitude of *Capella* with regard to *Regulus* (Delambre)	292	0	40
Longitude of *Regulus*, 1840, Airy (Smyth's Cycle)	147	36	20
	439	37	0
	360	0	0
	79	37	0
Precession	55	0	0
Longitude of *Capella* 2120 B.C.	24	37	0

The latitude of Babylon may be taken at $32\frac{1}{2}°$. We have generally solved the problem of the heliacal rising approximately



by means of the globe. And considering the vagueness of our information about the phenomenon itself, we think perhaps that this method is near enough for the purpose. Assuming that a 1^m star rises heliacally when it is 12° in direct altitude above the

Sun at the horizon, we find that *Capella* rose heliacally when the Sun was about 15° short of the star in longitude. But this is the position of the Sun on 1 Nisan in the normal year, subject to a small correction. So that the coincidence of the beginning of the year with the rising of *Icu* is fairly satisfied by the position of *Capella* at the given date.

To explain the occurrence of these different phenomena at morning and evening, at the same time of the year, we subjoin the following figures, which represent roughly the appearance of the quarters of the sky in the neighbourhood of the rising and setting Sun respectively at this time.

The evening position, "parallel to *Capella*," for a body moving in the ecliptic, is marked by a nearly level line of stars at about the same altitude, the other chief stars being *α Orionis* and *Sirius*. This line cuts the ecliptic some 3° above the foot of the latitude perpendicular from *Capella*.

The intersection of this horizontal line with the ecliptic is possibly to be regarded as the true starting-point of the calendar. The allowance, to be added to the equinoctial longitude of *Capella* on this account, varies a little with the change of position of the starry sphere; but it is not far from 3° within somewhat wide limits, both of precession and diurnal motion.

Then the longitude of the point "parallel to *Icu*" would be *Capella's* longitude + 3° = 27½° say. Whence

1 Nisan	Sun's longitude in normal year	=	12½°	{from Equinox 2120 B.C.}
	„ „ mean year	=	− 2½	
	„ „ latest year	=	−16½	

and

	d	
Earliest equinox	= −12½	Nisan
	(= 17½	Adar)
Mean „	= 2½	Nisan
Latest „	= 16½	„

The equinox will vary with the date, being earlier for later dates and later for earlier dates, to the extent of 1^{d} for every 71 years nearly.

In the present paper we have explained the most essential parts of our conclusions as to the Babylonian Calendar. We hope, on a future occasion, to discuss other portions of the Babylonian Astronomy.

An Invention for giving perfectly uniform Rotary Motion in Driving Clocks. By H. C. Russell, Esq., Director of the Sydney Observatory.

The Clock now to be described was designed to give uniform motion to a Barrel-Chronograph, and the result is perfectly satisfactory; so much so that the driving weight may be varied 30 per cent. without producing *any change* in the rate.

I have applied the same form of governor to a telescope clock, and it keeps a star on the wire as if it formed part of it; and there is good reason to suppose that the same governor applied to the train of a standard clock would give better results than any yet obtained from the single pendulum.

These are strong statements; but they will, I think, be confirmed by what follows:—

In design the clock is very simple, and it seems strange that a similar arrangement was not long since devised. It will be easily understood by the aid of the following short description and two diagrams.

Fig. I. is a general view of the clock, showing the train of wheels, ending in a pair of bevel wheels at the top of the clock case. The object of these is to make the escape wheel axis vertical, and to have it project through the top of the clock case at N enough to carry the wheel D (Figs. I. and II.) and the parts attached to it, which are (1) the arm A (Fig. II.) projecting from the first wheel in the train; (2) the spring B; (3) a small train of wheels C, ending in a fan-fly which makes two hundred revolutions for one of the first wheel J; (4) projecting up from the arm A at the point E is a small steel pin half an inch long, which, when at rest, forms a continuation of the axis of the wheel D, but when in motion leaves the centre, taking the arm A and thus turning the wheel J and setting the fan in motion. This pin E forms the connection between the clock train and the pendulums, for it works in a hole in the lower end of the rod K, and this is connected with each of the pendulums by the rods H, H, H, H; they are fastened to K by small steel springs, and to the pendulum rods by small ball and socket joints. The rod K, together with part of the weight of the rods H, H, H, H, is held up by a steel wire at G.

The axis of the wheel J and the arm A is a steel pin fixed to, and standing up vertical from, the surface of the wheel D; the arm A therefore moves in a plane parallel to the surface of D, and when it leaves the position shown in the drawing it carries the pin E along the dotted curve EO, E being always vertical. In moving from the centre, E bends the light steel spring B, which acts as a resisting force to the increase of its eccentricity. It is obvious that if E moves slowly the wheels and fan will offer very little, if any, resistance; but it cannot be moved suddenly, owing to the resistance offered by the train and fan. The

Fig. 2.

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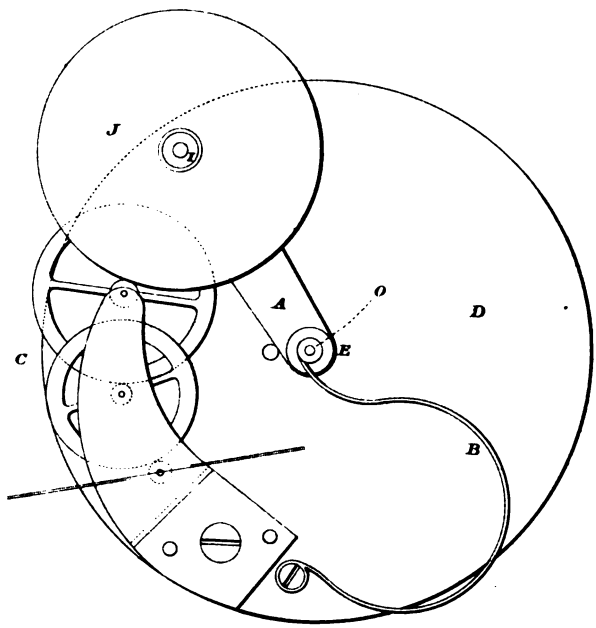
Fig. 2.



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strength of the spring B must be learned by experiment; if it is too strong, the clock will gain with increased weight, and if it is too weak the clock will lose under the same conditions. The one in use in this clock is about as strong as the balance spring in an American clock.

There is nothing unusual about the pendulums, except that they are hung by two springs instead of one; the bobs are lead, and each of them weighs 15 lb.; the time is half a second. The train is an ordinary clock train, and requires no mention here.

When all the parts of this clock are in the position shown, and a weight is applied to the driving barrel, the wheel D begins to move, and a slight impulse given to one of the pendulums pushes the pin E from the centre of D, and it at once sets the other three pendulums in motion, and their arcs gradually increase until the force necessary to drive them is equal to the driving weight. Should the weight be increased, the pendulum arcs, and with them the eccentricity of E, increase until equilibrium is again attained. Now, if the experiment of increasing the weight be tried without the spring B, the clock will be found to go slower, like an ordinary pendulum clock under increased weight; but if the spring B be carefully adjusted, 30 per cent. added to the weight will not produce *any change in rate*, even when the test is a first-class sidereal clock marking the chronograph cylinder every second, a test which, as is well known, would at once show the smallest change of rate.

One difficulty, which in the earlier experiments promised to be a very serious one, was overcome by introducing the small train of wheels. It was this: if all the pendulums were not perfectly isochrone, the pin E would very soon cease to move in a circle, and would describe an ellipse, and have therefore an *irregular* rotary motion. Independent of the difficulty of making four pendulums isochrone, it is necessary that the escapement should have in it something to prevent the pin E from moving in an ellipse, and such the train of wheels and fan provide, because they strongly resist sudden changes of eccentricity, at the same time that they allow slow changes, such as those caused by friction, to go on with little or no resistance. In this is involved an important principle, viz.: If the pendulums are not isochrone, the time given in each revolution of the escape wheel is the *mean* of the times of a double oscillation for each pendulum. So that, if four nearly compensated pendulums in a standard clock were thus connected, the rate under changes of temperature would be the mean of the four rates. And since the spring, as before shown, counteracts the effect of changes in the friction or driving power, there is good reason to suppose that such a clock would keep better time than a clock with only one pendulum, subject to the many changes of impulse given to it by the train.

Such is the clock now used to work the barrel chronograph from which the sample sheets sent herewith have been taken.

Some of these have been run without change of weight, in one the weight has been changed twice, in another only one change; but I have confined the experiments so far to a change of 30 per cent. in the driving weight, because they take so much time to make them.

It is necessary to add that this clock is the first made of the kind, and the wheels are old ones adapted to the requirements; but in some of them imperfections are known to exist, and these appear as slight errors in the seconds marks. I have been obliged to send out of the colony to get the wheels made with the accuracy required, and it will be some time before the clock intended for the chronograph is made; but the results with this rough experimental clock are so good that I thought they ought to be published.

Four pendulums are not essential; two give very good results provided the arms H be not too short, say not less than 12 inches. Such a clock I have applied to the 11½-inch Equatoreal, and the motion is perfect, keeping a star on the wire as if it were part of it, so long as changing refraction does not interfere. By a very simple contrivance the rate is changed to suit the Moon or planets. This is effected by continuing the pendulum rods two inches below the bobs and fixing brass disks on the end of them; upon these weights can be placed having a known effect upon the rate, and for convenience they are stamped with the number of seconds change they produce in ten minutes; so that it is only necessary to look at the *Nautical Almanac* and see the Moon's change in R.A. in ten minutes, and select these weights, in order to make the telescope follow the Moon exactly.

A few words about the origin of the clock may not be out of place here. Last year a new barrel chronograph was required for Sydney Observatory, and Mr. William Barraclough, of Sydney, undertook to make it. When the cylinder and pen carriage were completed, experiments were made with several well-known forms of governor, in order to secure uniform rotation of the cylinder. None of these would give such uniform motion as I required; and Mr. Barraclough said that some years since, when in England, he had been asked to make a clock that would not *tick*, and that after some trouble he had succeeded, using only one pendulum; but that he thought he could make perfectly uniform motion with two oscillating pendulums, and at my request he made a rough model with two pendulums working at right angles to each other. Each pendulum was connected with the eccentric pin by means of a double (Watt's) parallel motion, so arranged that the part of the rod connected with E moved in a straight line parallel to the surface of the wheel D; and the motion of the eccentric pin was made stiff by means of a cloth washer under the arm A; this obliged E to move in a circle, and at the same time allowed the pendulum arcs to increase if necessary. This model proved that it was possible to get smooth rotary motion from two oscillating pen-

dulums; but when it came to be tested for uniform rotation, I found the friction of the cloth washer so uncertain that the governor was of little value. Several other forms of friction under the arm A gave a like result: without any friction under A, elliptical motion was always sooner or later set up by the pin E, and at one time I almost gave up hope of overcoming the difficulty; for these experiments made it obvious that E must be *free* to move and yet have some *resistance to sudden change of position*, so that it could not move in an ellipse. I then devised the small train and fan-fly to meet these requirements, and the four straight rods connecting the pendulums with the rod K, instead of the rather complex parallel motion of the model. In its present form the clock seems only to require for its perfection that the spring B shall not be changed by change of temperature, and this I have no doubt can be accomplished by making it of a particular length and form.

I have purposely avoided dimensions, because these may be varied at pleasure. For instance, seconds pendulums may be used and the wheel D would then turn in two seconds; but I prefer and have used half-seconds pendulums. So the weight of the pendulums and the strength of their supporting springs may vary; but it is not desirable to have the supporting springs stronger than is necessary to carry the weight. The only dimension that perhaps ought to be given is the length of the rods H. If these are short they do not work well. Those I have in use are nine inches long, and they would work better if longer, because they would then move near the direction of the swing of the pendulum and not tend to twist it so much, as they move from side to side with the eccentric.

Sydney Observatory,
1879, *March* 18.

On the Applicability of the Mean Refractions of Bessel's "Fundamenta" to the Washington Observations. By A. M. W. Downing, Esq.

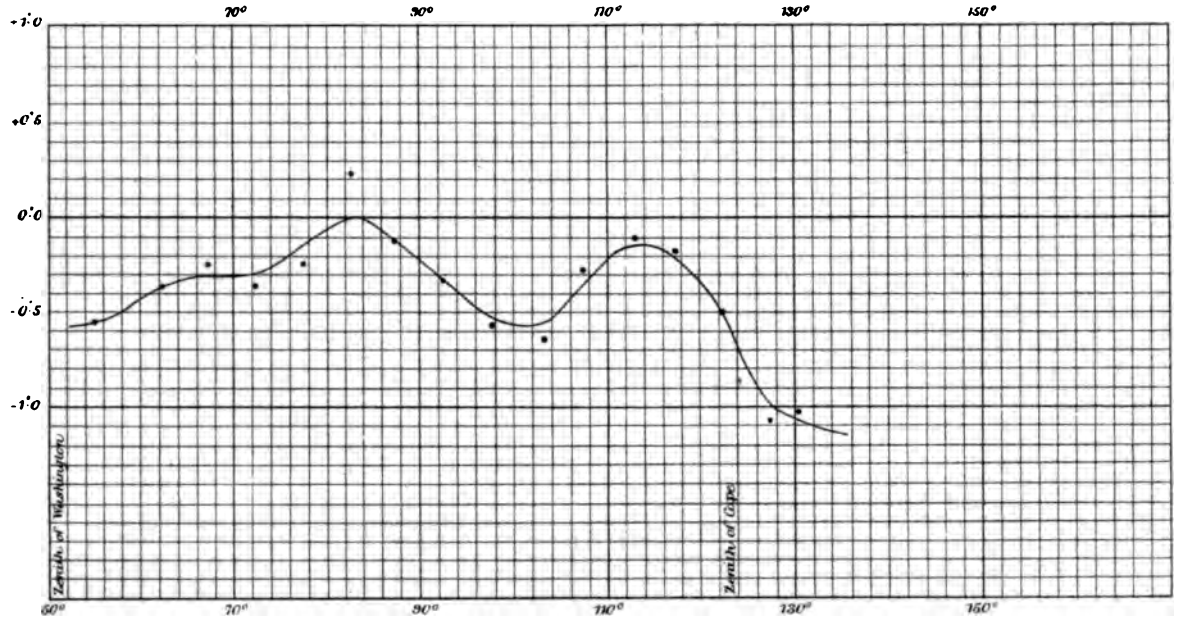
As it appears from recent investigations, the results of which are exhibited in an Addendum to the Introduction to the Greenwich Nine-Year Catalogue, that the refractions of the *Tabulæ Regiomontanæ* unaltered, at all events as far as 85° Z.D., represent fairly enough the Greenwich observations, I thought that it would be interesting to try whether the N.P.D.'s of the Washington Catalogue for 1860 are in satisfactory accord with observations made in the Southern Hemisphere, as these N.P.D.'s are reduced with the refractions of the *Tabulæ* unaltered. I have

accordingly made a comparison between the N.P.D.'s of the Cape (1860) and Washington Catalogues—a work of no small magnitude, as there are just 400 stars common to the Catalogues which are available for the comparison, omitting those whose places depend on a single observation. The stars have been arranged in order of N.P.D., and the proper motions given in the Cape Catalogue applied to the Washington places; they have then been taken in groups of 5° each, and the means of the differences taken for each group. These mean differences have been laid down on cross-ruled paper, and a curve (*see* diagram) drawn through the points. The following table gives the differences as computed and as read off from the curve :—

Z.D. at Washington.	N.P.D.	Number of Stars.	Cape—Washington.	
			Means.	Curve.
° °	° ′		″	″
0—9	55 24	8	−0·53	−0·53
9—14	62 32	19	−0·37	−0·37
14—19	67 45	38	−0·25	−0·30
19—24	72 13	16	−0·35	−0·30
24—29	77 33	24	−0·23	−0·16
29—34	82 31	27	+0·23	0·00
34—39	87 30	23	−0·11	−0·11
39—44	92 35	23	−0·32	−0·32
44—49	97 55	27	−0·57	−0·53
49—54	103 14	14	−0·63	−0·56
54—59	107 20	33	−0·28	−0·36
59—64	113 4	22	−0·10	−0·16
64—69	117 26	59	−0·18	−0·22
69—74	122 10	40	−0·50	−0·50
74—78	127 2	14	−1·09	−0·97
78—82	130 23	8	−1·03	−1·07
82—85	134 10	2	−3·50	—
85—87	136 49	2	−3·85	—

In order to assure myself of the reality of the discordances in the last three groups, I have computed the differences of the Washington and Melbourne (1870) places south of N.P.D. 129°, the Melbourne places being reduced to the Cape standard by the table given on page 176 of the present volume of the *Monthly Notices*. The following is the result:—

COMPARISON OF THE NORTH POLAR DISTANCES OF THE CAPE (1860) AND WASHINGTON (1860) CATALOGUES.



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N.P.D. ° ′	Number of Stars.	Melbourne—Washington. ″
130 16	16	−1·32
134 25	3	−3·62
136 49	2	−3·96

The difference at Z.D. 82°—85° is untrustworthy, as one of the stars employed, occurring in both the Cape and Melbourne comparisons, is very discordant; if this star, whose place in the Washington Catalogue depends on only two observations, be rejected, the mean of the comparisons with the places in the Southern Catalogues is −1″·55. I propose to adopt this as the difference for N.P.D. 134° 21′.

The readings from the curve for every 5° (with computed values below 80° Z.D.) then give—

Z.D. °	N.P.D. ° ′	Cape—Washington. ″
4	55	−0·55
9	60	−0·43
14	65	−0·33
19	70	−0·31
24	75	−0·25
29	80	−0·07
34	85	−0·05
39	90	−0·22
44	95	−0·44
49	100	−0·56
54	105	−0·50
59	110	−0·23
64	115	−0·17
69	120	−0·36
74	125	−0·80
79	130	−1·07
83 15	134 21	−1·55
85 43	136 49	−3·85

It is evident that, in addition to discordances arising from other causes than refraction, the tabular refractions used at Washington must be diminished in order that the observations may agree with those made at the Cape. Now, as far as 85° Z.D. the mean refractions of the *Fundamenta* are those of the *Tabulæ* diminished in the proportion of 1 : 0·996718, and a preliminary calculation showed that this was very nearly the proportion in which the Washington refractions should be diminished. By substituting the mean refractions of the *Fundamenta* for those of the *Tabulæ*, the discordances are reduced as follows:—

Z.D.				Z.D.			
°	"	to	"	°	"	to	"
4	−0·55	to	−0·54	49	−0·56	to	−0·34
9	−0·43		−0·40	54	−0·50		−0·24
14	−0·33		−0·28	59	−0·23		+0·07
19	−0·31		−0·24	64	−0·17		+0·23
24	−0·25		−0·17	69	−0·36		+0·13
29	−0·07		+0·03	74	−0·80		−0·13
34	−0·05		+0·07	79	−1·07		−0·15
39	−0·22		−0·07	83½	−1·55		+0·01
44	−0·44		−0·26	85½	−3·85		−0·62

If then the Washington observations were reduced with the mean refractions of the *Fundamenta* and the meteorological corrections of the *Tabulæ*, the agreement with the Cape observations would be very satisfactory if we may assume that the relative correction for errors of the adopted latitudes is small.

It appears from this investigation, and also from the comparison of the Cape and Greenwich Catalogues referred to above, that the tabular refractions used in the reduction of the Cape observations also require to be somewhat diminished.

1879, *June* 10.

Ephemeris for Physical Observations of Mars, 1879–80. By A. Marth, Esq.

Greenwich Noon.	Angle of Posit. of ♂'s Axis.	Areographical W. Long. of the Centre of ♂'s Disk.	Diff.	Areographical Lat. of ♂'s Disk.	Diameter.	Amount of Greatest Defect of Illumination.	Posit.	Areocentric Ang. between Earth & Sun.
1879.	°	°	°	°	"	"	°	°
July 29	143·34	299·53		−17·64	10·38	1·66	250·39	47·11
			700·63					
31	143·19	280·16		17·29	10·51	1·67	250·68	47·03
			·64					
Aug. 2	143·06	260·80		−16·93	10·64	1·69	250·98	46·93
			·66					
4	142·95	241·46		16·58	10·78	1·70	251·28	46·82
			·68					
6	142·85	222·14		16·22	10·92	1·72	251·58	46·70
			·71					
8	142·77	202·85		15·87	11·06	1·73	251·89	46·56
			·73					
10	142·71	183·58		15·52	11·21	1·74	252·20	46·40
			·75					
12	142·66	164·33		15·16	11·36	1·75	252·52	46·22
			·78					
14	142·62	145·11		14·81	11·51	1·76	252·84	46·03
			·79					
16	142·60	125·90		14·47	11·67	1·77	253·15	45·81
			·82					
18	142·59	106·72		14·12	11·83	1·77	253·47	45·58
			·85					

Greenwich Noon.	Angle of Posit. of ♂'s Axis.	Areographical W. Long. of the Centre of Diff.	Lat. ♂'s Disk.	Diameter.	Amount and Posit. of Greatest Defect of Illumination.		Areocentric Ang. between Earth & Sun.
1879.	°	°	°	″	″	°	°
Aug. 20	142·60	87·57	13·79	11·99	1·78	253·79	45·32
		·88					
22	142·61	68·45	13·46	12·16	1·78	254·11	45·04
		·90					
24	142·64	49·35	13·13	12·34	1·79	254·42	44·74
		·93					
26	142·67	30·28	12·81	12·52	1·79	254·74	44·41
		·95					
28	142·71	11·23	12·50	12·70	1·78	255·05	44·06
		700·99					
30	142·76	352·22	12·20	12·89	1·78	255·35	43·68
		701·02					
Sept. 1	142·82	333·24	−11·91	13·08	1·78	255·65	43·27
		·04					
3	142·88	314·28	11·63	13·27	1·77	255·94	42·84
		·08					
5	142·94	295·36	11·37	13·48	1·76	256·23	42·37
		·11					
7	143·01	276·47	11·11	13·68	1·75	256·51	41·88
		·14					
9	143·08	257·61	10·87	13·89	1·73	256·78	41·35
		·18					
11	143·15	238·79	10·64	14·11	1·71	257·04	40·78
		·22					
13	143·22	220·01	10·43	14·33	1·69	257·29	40·18
		·25					
15	143·29	201·26	10·24	14·55	1·66	257·53	39·54
		·30					
17	143·36	182·56	10·07	14·78	1·63	257·75	38·85
		·34					
19	143·42	163·90	9·91	15·02	1·60	257·96	38·13
		·38					
21	143·48	145·28	9·78	15·25	1·56	258·16	37·36
		·42					
23	143·53	126·70	9·67	15·49	1·52	258·34	36·55
		·47					
25	143·58	108·17	9·58	15·73	1·47	258·50	35·69
		·51					
27	143·62	89·68	9·51	15·98	1·42	258·65	34·79
		·56					
29	143·65	71·24	9·46	16·22	1·37	258·77	33·83
		701·61					
Oct. 1	143·67	52·85	−9·44	16·47	1·31	258·88	32·83
		·66					
3	143·68	34·51	9·45	16·72	1·25	258·97	31·77
		·71					
5	143·68	16·22	9·48	16·96	1·19	259·03	30·66
		·76					
7	143·68	357·98	9·54	17·20	1·12	259·08	29·49
		·82					
9	143·66	339·80	9·62	17·44	1·04	259·10	28·26
		·87					
11	143·63	321·6	9·73	17·67	0·96	259·09	26·98
		·92					

Greenwich Noon.	Angle of Posit. of ♂'s Axis.	Areographical W. Long. of the Centre of ♂'s Disk.	Diff.	Lat.	Diameter.	Amount of Greatest Defect of Illumination.	Posit.	Areocentric Ang. between Earth & Sun.
1879.	°	°	°	°	″	″	°	°
Oct. 13	143·59	303·59		9·88	17·90	0·88	259·06	25·65
			701·98					
15	143·54	285·57		10·05	18·12	0·80	259·01	24·25
			702·03					
17	143·48	267·60		10·24	18·32	0·72	258·93	22·80
			·08					
19	143·41	249·68		10·46	18·51	0·63	258·82	21·30
			·13					
21	143·33	231·81		10·71	18·69	0·55	258·70	19·74
			·18					
23	143·25	213·99		10·98	18·85	0·47	258·54	18·13
			·22					
25	143·16	196·21		11·27	18·99	0·39	258·36	16·48
			·27					
27	143·07	178·48		11·58	19·11	0·32	258·15	14·79
			·31					
29	142·97	160·79		11·91	19·20	0·25	257·92	13·05
			·34					
31	142·88	143·13		12·26	19·27	0·19	257·65	11·29
			702·36					
Nov. 2	142·78	125·49		−12·62	19·32	0·13	257·34	9·49
			·40					
4	142·68	107·89		12·98	19·34	0·09	257·0	7·68
			·41					
6	142·59	90·30		13·36	19·32	0·05	256·5	5·84
			·43					
8	142·50	72·73		13·74	19·28	0·03	255·8	4·00
			·43					
10	142·42	55·16		14·12	19·22	0·01	254·4	2·15
			·43					
12	142·35	37·59		14·49	19·12	0·00	...	0·06
			·43					
14	142·28	20·02		14·86	18·99	0·00	...	1·52
			·42					
16	142·22	2·44		15·22	18·84	0·02	77·9	3·26
			·39					
18	142·16	344·83		−15·57	18·66	0·04	77·1	5·12
			·38					
20	142·11	327·21		15·91	18·46	0·07	76·6	6·88
			·34					
22	142·07	309·55		16·23	18·23	0·10	76·16	8·60
			·30					
24	142·04	291·85		16·53	17·99	0·15	75·83	10·27
			·27					
26	142·01	274·12		16·81	17·73	0·19	75·56	11·91
			·22					
28	141·99	256·34		17·17	17·46	0·24	75·31	13·49
			·18					
30	141·97	238·52		17·30	17·17	0·29	75·08	15·01
			702·13					
Dec. 2	141·95	220·65		−17·52	16·87	0·35	74·88	16·49
			·08					
4	141·94	202·73		17·71	16·57	0·40	74·69	17·91
			702·03					

Greenwich Noon.	Angle of Posit. of ♂'s Axis.	Areographical W. Long. of the Centre of ♂'s Disk.	Diff.	Areographical Lat. of ♂'s Disk.	Diameter.	Amount and Posit. of Greatest Defect of Illumination.		Areocentric Ang. between Earth & Sun.
1879.	°	°	°	°	″	″	°	°
Dec. 6	141·92	184·76		17·88	16·25	0·46	74·53	19·28
			701·98					
8	141·91	166·74		18·02	15·94	0·51	74·38	20·58
			·92					
10	141·90	148·66		18·14	15·62	0·56	74·25	21·83
			·87					
12	141·89	130·53		18·24	15·30	0·61	74·14	23·02
			·82					
14	141·88	112·35		18·32	14·98	0·66	74·05	24·15
			·76					
16	141·88	94·11		18·38	14·66	0·70	73·97	25·22
			·71					
18	141·87	75·82		18·41	14·35	0·74	73·90	26·23
			·66					
20	141·86	57·48		18·42	14·04	0·78	73·85	27·19
			·61					
22	141·85	39·09		18·41	13·74	0·81	73·82	28·10
			·56					
24	141·84	20·65		18·38	13·44	0·84	73·80	28·95
			·52					
26	141·83	2·17		18·33	13·14	0·87	73·80	29·75
			·47					
28	141·82	343·64		18·26	12·85	0·89	73·81	30·50
			·43					
30	141·82	325·07		18·17	12·57	0·91	73·83	31·21
			701·39					
1880.								
Jan. 1	141·81	306·46		−18·07	12·30	0·93	73·87	31·87
			·35					
3	141·80	287·81		17·95	12·03	0·94	73·92	32·49
			·32					
5	141·80	269·13		17·81	11·77	0·95	73·98	33·07
			·28					
7	141·81	250·41		17·66	11·52	0·96	74·06	33·61
			·25					
9	141·82	231·66		17·49	11·28	0·97	74·15	34·11
			·21					
11	141·83	212·87		17·30	11·04	0·97	74·25	34·57
			·19					
13	141·85	194·06		17·10	10·81	0·98	74·37	34·99
			·15					
15	141·88	175·21		16·89	10·58	0·98	74·49	35·39
			·13					
17	141·91	156·34		16·66	10·37	0·98	74·63	35·75
			·11					
19	141·95	137·45		16·42	10·16	0·97	74·79	36·07
			·08					
21	141·99	118·53		16·17	9·95	0·97	74·95	36·37
			·06					
23	142·05	99·59		15·91	9·75	0·96	75·12	36·65
			·04					
25	142·11	80·63		15·63	9·56	0·96	75·31	36·89
			·02					
27	142·19	61·65		15·34	9·38	0·95	75·51	37·11
			701·00					

Greenwich Noon.	Angle of Posit. of ♂'s Axis.	Areographical W. Long. of the Centre of ♂'s Disk.	Diff.	Lat. ♂'s Disk.	Diameter.	Amount and Posit. of Greatest Defect of Illumination.		Areocentric Ang. between Earth & Sun.
1880.	°	°	°	°	″	″	°	°
Jan. 29	142·27	42·65		15·04	9·20	0·94	75·72	37·31
			700·98					
31	142·36	23·63		14·73	9·03	0·93	75·94	37·48
			700·97					
Feb. 2	142·47	4·60		−14·41	8·86	0·92	76·16	37·64
			·95					
4	142·58	345·55		14·08	8·70	0·91	76·40	37·77
			·94					
6	142·71	326·49		13·74	8·54	0·90	76·66	37·88
			·92					
8	142·85	307·41		13·39	8·39	0·89	76·92	37·97
			·92					
10	143·00	288·33		13·03	8·24	0·88	77·19	38·04
			·90					
12	143·16	269·23		12·66	8·10	0·86	77·47	38·09
			·89					
14	143·34	250·12		12·28	7·96	0·85	77·77	38·13
			·88					
16	143·53	231·00		11·89	7·83	0·84	78·07	38·15
			·86					
18	143·73	211·86		11·50	7·70	0·82	78·38	38·16
			·86					
20	143·94	192·72		11·10	7·57	0·81	78·70	38·15
			700·86					
22	144·17	173·58		−10·69	7·45	0·79	79·03	38·13

1879 Aug. 14. Winter solstice of *Mars'* northern hemisphere.
1880 Jan. 21. Spring equinox ,, ,, ,,

The observations of the position-angles of the south solar spot, made in 1877, by Asaph Hall (*Astron. Nach.*, No. 2174), and by Schiaparelli (*Osservazioni astronomiche e fisiche sull' asse di rotazione e sulla topografia del planeta Marte.* Roma, 1878), indicate that the determination of the direction of the planet's axis, deduced from the scanty observations of 1830–37, requires considerable corrections. A trustworthy new determination will only be feasible, in case proper observations are secured during at least the two next oppositions, 1879 and 1881–82. For this purpose several methods of observing will have to be tried and tested, in order that the best method for giving correct results may be ascertained. The want of sufficient agreement between the position-angles of Hall and Schiaparelli, which is obviously due to their different modes of observing, and which must be cleared up before the observations can be used with confidence, leaves considerable doubt respecting the amount of the correction of the predicted position-angles of the axis in 1877; but since both series indicate that the assumed inclination is chiefly in fault, I have thought it right to introduce in the present Ephemeris preliminary corrections, which will probably diminish the differences between the predicted and

observed position-angles of the axis, and which will considerably reduce the amount of the ultimate corrections required. The values, adopted in the computations, of the inclination and node of the plane of the equator of *Mars* in reference to that of the Earth are for 1880·0, inclination 36°·260, node 47°·945. As in previous cases, the data of the Ephemeris are to be interpolated directly for the times of the observations, the equation of light having already been duly taken into account. The amount q, and the position-angle Q of the greatest defect of illumination, may serve in reducing position-angles and distances, which have been observed in reference to the assumed centre of the illuminated disk, to the true centre of the planet. But the reductions depend on what is assumed by observers as the centre of the illuminated disk. If that point is fixed upon which bisects that diameter of the disk, which is perpendicular upon the line of cusp, or in position-angle Q, the distance between the true centre and the assumed centre is $\frac{1}{2}q$. But if the centre of gravity of the apparent disk or the point, lines laid through which bisect the illuminated area, is assumed to be the observed centre, its distance from the true centre is $\frac{4q}{3\pi}$. If p_1 and s_1 are the observed angle and distance referred to the assumed centre, the values p and s referred to the true centre are found in the first case by

$$s \sin (p-p_1) = \tfrac{1}{2}q \sin (p_1-Q),$$
$$s \cos (p-p_1) = s_1-\tfrac{1}{2}q \cos (p_1-Q),$$

or, when s_1 is not small, by approximate formulæ. In the second case, $\frac{4q}{3\pi} = [9{\cdot}6278]$, q is to be substituted for $\frac{1}{2}q$.

A reference must be sufficient to the remarks made on page 307 of vol. xxxvii. respecting observations of the times and places of the passages across the central meridian of all the most distinct and well-defined points on the planet's surface which may serve as fundamental points of Areography. If observers cannot be induced to make these observations, the topography of the surface of *Mars* must remain in an unsatisfactory state.

The following list gives the areographic longitude and latitude of the centre of *Mars*, and also its apparent diameter, for the times of a number of sketches made chiefly during the oppositions of 1871, 1873, and 1877. A similar list of the sketches of 1862 and 1864 is to be found in the *Monthly Notices*, vol. xxxvii., pp. 305–307, and another in the *Astronomical Register*, vol. xv., pp. 153–154.

The present list comprises the sketches of—

Boeddicker, O. (5 plates with 10 sketches in the *Veröffentlichungen von der Kgl. Sternwarte zu Göttingen*, 1878. It is assumed that m. Z. B. means "mittlere Zeit Berlin.")

Burton, Ch. (6 sketches, published in M. T. Terby's *Aréographie*, Bruxelles, 1874. Figs. 10, 11, 20, 30, 42, 47.)

Crossley & Gledhill.	(1 sketch in Terby's *Aréographie*. Fig. 18.)
Cruls, Luiz.	(13 plates with 26 sketches in *Observatoire Impérial de Rio de Janeiro*, "Mémoire sur *Mars*." In the 6 cases marked corr., the assigned times are the corrected ones, not those on the plates.)
Dreyer, J.	(12 sketches, with "Notes on the physical appearance of the planet *Mars*, as seen with the Three-Foot Reflector at Parsonstown, during the opposition of 1877," in the *Scientific Transactions of the Royal Dublin Society for the year* 1878.)
Gledhill, J.	(4 sketches in Terby's *Aréographie*. Figs. 41, 46, 51, 52.)
Green, N.	(6 sketches of 1873 in the *Astronomical Register* for July, 1873. 5 of these sketches are reproduced in Terby's *Ar.* (Figs. 15, 43, 44, 48, 49.)
	(12 sketches of 1877, made at Madeira, to be published in Vol. xliv. of the *Memoirs of the Royal Astronomical Society*.)
Knobel, E. B.	(17 sketches of 1873 in the *Monthly Notices*, vol. xxxiii., p. 476, and an additional sketch in Terby's *Ar.* Fig. 31.)
Knott, G.	(5 sketches in Terby's *Ar.* Figs. 9, 26, 33, 34, 40.)
Lehardelay	(2 sketches in Terby's *Ar.* Figs. 32, 54, the times being assumed to be Paris times.)
Lohse, O.	(6 sketches of 1871, Nos. 5, 7, 8, 10, 11, 12 on Tafel 6 of the *Astron. Beobachtungen zu Bothkamp*.)
	(12 sketches of 1877 on Tafel 8 of the *Publicationen des Astrophysikalischen Observatoriums zu Potsdam*. No. 2.)
	(8 sketches of 1873, represented by woodcuts on pp. 127, 128 of the same publication.)
Niesten, L.	(5 plates with 42 sketches in "*Observations sur l'Aspect physique de la planète Mars pendant l'opposition de* 1877. Brux. 1877.)
Schmidt, J.	(5 sketches in Terby's *Ar.* Figs. 8, 16, 17, 21, 39.)
Secchi, A.	(1 sketch of 1864 in Terby's *Ar.* Fig. 45.)
Terby, M. F.	(12 sketches, fig. 15–26, in "Observations de *Jupiter* et de *Mars* faites à Louvain . . . en 1873." *Bulletin de l'Académie R. de Belgique*, vol. 36, No. 11.)
	(15 sketches in "Etudes sur la planète *Mars*," 11me notice. *Bulletin*, vol. 45, No. 1. The times are assumed to be Brussels times.)
Trouvelot, L.	(4 sketches on plate 22 of vol. 8 of the *Annals of Harvard College Observatory*.)
Vogel, H.	(3 sketches, Nos. 4, 6, 9, on Tafel 6 of the *Astron. Beobachtungen zu Bothkamp*.)
Webb, T. W.	(3 sketches in Terby's *Ar.* Figs. 13, 29, 53.)
Weinek, L.	(3 sketches in the paper *Sirius*, vol. xii., 1.)
Wilson, T. M.	(3 sketches in Terby's *Ar.* Figs. 14, 22, 50.)

Where the times of the commencement and of the completion of the sketch are given, the longitude of the centre of the disk refers to the mean of the times.

Areographical Long.	Areographical Lat. of the Centre of the Disk.	Diameter.		Times assigned to the Sketches.				
°	°	″				h m	h m	
2·4	−22·4	24·8	Cruls VII. 1	1877	Sept. 1	7 30		Rio de Janeiro.
5·2	+21·1	16·2	Green, No. 5 (*Ar.* f. 48)	73	May 16	9 15		Greenwich.
6·6	−22·4	24·8	Green 1	77	Sept. 1	10 40		Greenwich.
6·8	+25·1	14·3	Lehardelay (*Ar.* f. 32)	71	Mar. 23	10	—11	Paris.
7·5	+22·1	15·6	Trouvelot 2	73	May 24	9 30		Cambridge, Mass.
11·1	−24·2	20·4	Niesten III. 1	77	Oct. 6	8		Brussels.
14·8	−24·4	20·0	Niesten III. 3	77	Oct. 8	9 30		Brussels.
16·6	−24·5	19·8	Niesten III. 5	77	Oct. 9	10 30		Brussels.
18·7	+20·5	16·4	Knobel 7	73	May 12	7 45		Greenwich.
19·0	+25·0	14·3	Webb (*Ar.* f. 29)	71	Mar. 22	10 35		Greenwich.
19·4	−22·4	24·7	Terby 1	77	Aug. 30	10 30	—10 45	Brussels.
19·7	−24·2	20·4	Terby 13	77	Oct. 6	8 30	— 8 40	Brussels.
21·5	−24·4	20·0	Dreyer 11	77	Oct. 8	9 40		Greenwich.
24·2	+20·6	16·4	Terby f. 23	73	May 12	8 20	— 8 30	Brussels.
25·7	−24·1	20·8	Terby 12	77	Oct. 4	7 40	— 7 50	Brussels.
26·2	+21·5	16·0	Knobel 12	73	May 19	12 30		Greenwich.
27·8	−27·1	14·0	Niesten V. 1	77	Nov. 10	6 55		Brussels.
29·4	−24·1	20·8	Niesten II. 8	77	Oct. 4	8 (in text 11)		Brussels.
30·1	−22·5	24·8	Cruls VII. 2	77	Sept. 2	10 0		Rio de Janeiro.
30·9	+21·1	16·2	Knobel 10	73	May 16	11 0		Greenwich.

Areographical Long. and Lat. of the Centre of the Disk.		Diameter.		Times assigned to the Sketches.				
°	°	″				h m	h m	
96·4	−23·5	22·2	Terby 7	1877	Sept. 27	8 15		Brussels.
97·8	+19·9	16·5	Wilson (*Ar. f.* 50)	73	May 8	10 45		Greenwich.
100·5	−26·6	15·1	Niesten V. 3	77	Nov. 3	7 20		Brussels.
101·1	−23·8	21·4	Dreyer 9	77	Oct. 1	10 45 (in text 10ʰ 55ᵐ)		Greenwich.
103·3	−25·5	24·8	Cruls VIII. 1	77	Sept. 2	15 0 *corr.*		Rio de Janeiro.
104·3	−23·5	22·2	Terby 8	77	Sept. 27	8 40	8 55	Brussels.
109·6	−22·4	24·4	Cruls IV. 1	77	Aug. 24	10 0		Rio de Janeiro.
111·1	+24·4	13·9	Lehardelay (*Ar. f.* 54)	71	Mar. 11	10	11	Paris.
112·4	−26·6	15·3	Niesten IV. 12	77	Nov. 2	7 30		Brussels.
114·1	−23·5	22·3	Lohse 8	77	Sept. 26	9 27		Berlin.
114·6	−23·5	22·2	Niesten II. 6	77	Sept. 27	9 30		Brussels.
116·5	−23·4	22·5	Lohse 7	77	Sept. 25	9 0		Berlin.
130·2	−23·2	23·0	Niesten II. 2	77	Sept. 22	7 30		Brussels.
130·8	−22·4	24·1	Green 5	77	Aug. 21	12 30		Greenwich.
132·7	−23·7	21·8	Weinek 3	77	Sept. 29	12·5		Leipsig.
135·5	−23·6	21·9	Dreyer 8	77	Sept. 28	11 15		Greenwich.
135·8	−23·2	23·0	Lohse 6	77	Sept. 22	8 29		Berlin.
136·3	−23·4	22·5	Niesten II. 4	77	Sept. 25	9 45		Brussels.
140·4	−22·4	24·4	Cruls II. 2	77	Aug. 23	11 30		Rio de Janeiro.
141·2	−23·2	23·0	Niesten II. 3	77	Sept. 22	8 15		Brussels.

143·9	−23·5	22·1	Cruls XII. 2	77	Sept. 27	8 20	Rio de Janeiro.
147·3	+22·9	14·2	Knobel 17	73	June 8	8 30	Greenwich.
148·4	− 6·6	17·3	Secchi (*Ar.* f. 45)	64	Dec. 1	7	Rome.
150·1	−23·2	23·2	Niesten I. 7	77	Sept. 21	8 15	Brussels.
151·9	−23·2	23·2	Terby 6	77	Sept. 21	8 15— 8 30	Brussels.
155·3	−23·5	22·3	Cruls XII. 1	77	Sept. 26	8 30	Rio de Janeiro.
160·3	−23·2	23·2	Lohse 5	77	Sept. 21	9 33	Berlin.
161·1	−23·2	23·2	Niesten I. 8	77	Sept. 21	9	Brussels.
163·9	+18·4	16·5	Terby f. 19	73	Apr. 29	10 5 —10 15	Brussels.
165·0	−22·4	23·9	Cruls I. 2	77	Aug. 19	10 45	Rio de Janeiro.
166·2	−22·5	23·6	Cruls I. 1	77	Aug. 16	9 0	Rio de Janeiro.
167·5	−26·0	16·5	Niesten IV. 9	77	Oct. 26	6 45	Brussels.
170·5	−23·0	23·5	Lohse 4	77	Sept. 20	9 38	Berlin.
174·1	−23·2	23·0	Niesten I. 9	77	Sept. 22	10 30	Brussels.
175·5	−23·1	23·3	Green 6	77	Sept. 20	9 5	Greenwich.
185·8	−26·0	16·5	Niesten IV. 10	77	Oct. 26	8	Brussels.
189·3	−22·4	24·0	Cruls II. 1	77	Aug. 19	15 30 *corr.*	Rio de Janeiro.
190·0	−22·9	23·7	Terby 4	77	Sept. 17	8 30— 8 35	Brussels.
191·8	+24·0	13·3	Lohse No. 5	71	Mar. 2	11 9	Bothkamp.
193·5	−22·9	23·7	Lohse 3	77	Sept. 17	9 23	Berlin.
194·0	−23·2	23·2	Niesten II. 1	77	Sept. 21	11 15	Brussels.
201·1	−22·4	24·4	Cruls IV. 2	77	Aug. 24	16 15 *corr.*	Rio de Janeiro.

Areographical Long. and Lat. of the Centre of the Disk.		Diameter.		Times assigned to the Sketches.				
°	°	″				h m	h m	
96·4	−23·5	22·2	Terby 7	1877	Sept. 27	8 15		Brussels.
97·8	+19·9	16·5	Wilson (*Ar.* f. 50)	73	May 8	10 45		Greenwich.
100·5	−26·6	15·1	Niesten V. 3	77	Nov. 3	7 20		Brussels.
101·1	−23·8	21·4	Dreyer 9	77	Oct. 1	10 45 (in text 10^h 55^m)		Greenwich.
103·3	−25·5	24·8	Cruls VIII. 1	77	Sept. 2	15 0 *corr.*		Rio de Janeiro.
104·3	−23·5	22·2	Terby 8	77	Sept. 27	8 40—	8 55	Brussels.
109·6	−22·4	24·4	Cruls IV. 1	77	Aug. 24	10 0		Rio de Janeiro.
111·1	+24·4	13·9	Lehardelay (*Ar.* f. 54)	71	Mar. 11	10	—11	Paris.
112·4	−26·6	15·3	Niesten IV. 12	77	Nov. 2	7 30		Brussels.
114·1	−23·5	22·3	Lohse 8	77	Sept. 26	9 27		Berlin.
114·6	−23·5	22·2	Niesten II. 6	77	Sept. 27	9 30		Brussels.
116·5	−23·4	22·5	Lohse 7	77	Sept. 25	9 0		Berlin.
130·2	−23·2	23·0	Niesten II. 2	77	Sept. 22	7 30		Brussels.
130·8	−22·4	24·1	Green 5	77	Aug. 21	12 30		Greenwich.
132·7	−23·7	21·8	Weinek 3	77	Sept. 29	12·5		Leipzig.
135·5	−23·6	21·9	Dreyer 8	77	Sept. 28	11 15		Greenwich.
135·8	−23·2	23·0	Lohse 6	77	Sept. 22	8 29		Berlin.
136·3	−23·4	22·5	Niesten II. 4	77	Sept. 25	9 45		Brussels.
140·4	−22·4	24·4	Cruls II. 2	77	Aug. 23	11 30		Rio de Janeiro.
141·2	−23·2	23·0	Niesten II. 3	77	Sept. 22	8 15		Brussels.

232·3	−23·0	23·6	Green 8	77	Sept. 18	11 45	Greenwich.
232·4	+25·9	13·8	Lohse No. 10	71	Apr. 8	11 23	Bothkamp.
234·5	+22·5	15·2	Terby f. 26	73	May 29	8 30— 8 35	Brussels.
234·7	+22·6	15·0	Knobel 16	73	May 31	9 30	Greenwich.
235·4	+17·3	16·2	Knobel 2	73	Apr. 23	11 40	Greenwich.
236·7	−26·0	16·5	Niesten IV. 8	77	Oct. 26	11 30	Brussels.
236·8	+25·9	13·7	Lohse No. 11	71	Apr. 9	12 17	Bothkamp.
237·1	−25·4	17·6	Niesten IV. 5	77	Oct. 20	7 40	Brussels.
237·2	+26·0	13·6	Lohse No. 12	71	Apr. 10	12 55	Bothkamp.
237·9	−22·8	24·1	Niesten I. 4	77	Sept. 14	10	Brussels.
237·9	−22·9	23·5	Dreyer 6	77	Sept. 16	10 55	Greenwich.
239·9	+22·4	15·3	Green No. 2 (*Ar.* f. 43)	73	May 28	8	Greenwich.
240·9	−22·8	24·1	Terby 3	77	Sept. 14	10 —10 25	Brussels.
241·0	−22·9	23·8	Cruls XI. 2	77	Sept. 16	8 15	Rio de Janeiro.
244·0	+25·8	13·7	Gledhill (*Ar.* f. 52)	71	Apr. 8	11 30	Greenwich.
247·0	+25·8	13·9	Gledhill (*Ar.* f. 41)	71	Apr. 6	10 30	Greenwich.
248·2	−22·7	24·3	Boeddicker IV. 2	77	Sept. 12	10 5·9	Berlin.
248·7	+22·6	15·1	Knobel 15	73	May 30	9 50	Greenwich.
250·4	−22·8	24·0	Green 9	77	Sept. 15	11 10	Greenwich.
250·5	−25·4	17·6	Niesten IV. 4	77	Oct. 20	8 35	Brussels.
251·2	+17·3	16·2	Knobel 3	73	Apr. 23	12 15	Greenwich.
253·3	−25·3	18·0	Niesten IV. 3	77	Oct. 18	7 30	Brussels.

Areographical Long. and Lat. of the Centre of the Disk.		Diameter.		Times assigned to the Sketches.					
°	°	″				h m	h m	
201·4	+17·7	16·3	Terby f. 18	1873	Apr. 25	10 15	—10 25	Brussels.
207·7	−26·0	16·5	Niesten IV. 11	77	Oct. 26	9 30		Brussels.
209·1	−23·0	23·6	Green 7	77	Sept. 18	10 20		Greenwich.
210·4	+22·7	14·8	Lohse f. 7	73	June 2	9 45		Bothkamp.
211·5	+17·9	16·4	Knobel 4	73	Apr. 26	11 20		Greenwich.
213·0	+22·5	15·1	Green No. 1	73	May 30	7 30		Greenwich.
213·4	−22·2	23·0	Schmidt (*Ar.* f. 39)	62	Oct. 1	7 28		Athens.
215·0	−22·9	23·7	Terby 5	77	Sept. 17	10 15		Brussels.
215·7	−22·4	24·4	Cruls V. 1	77	Aug. 24	17 15	*corr.*	Rio de Janeiro.
218·6	−22·9	23·7	Niesten I. 6	77	Sept. 17	10 30		Brussels.
220·1	+17·3	16·2	Terby f. 17	73	Apr. 23	10 10	—10 40	Brussels.
220·2	−22·9	23·9	Cruls XI. 1	77	Sept. 16	6 50		Rio de Janeiro.
220·5	−23·2	23·1	Weinek 2	77	Sept. 21	13·6		Leipzig.
221·1	+24·0	13·2	Vogel No. 4	71	Feb. 28	11 57		Bothkamp.
221·7	−22·8	24·0	Niesten I. 5	77	Sept. 15	9 30		Brussels.
226·6	−23·0	22·6	Knott (*Ar.* f. 40)	62	Oct. 8	11		Greenwich.
226·8	−23·6	22·1	Cruls XIII. 1	77	Sept. 27	14 0	*corr.*	Rio de Janeiro.
227·4	−25·4	17·6	Niesten IV. 7	77	Oct. 20	7		Brussels.
229·0	−22·9	23·7	Dreyer 7	77	Sept. 17	10 55		Greenwich.
232·2	−25·4	17·6	Niesten IV. 6	77	Oct. 20	7 20		Brussels.

281·1	−25·0	18·6	Niesten III. 8	77	Oct. 15	7 30	Brussels.
282·2	+25·8	13·9	Burton (*Ar.* f. 10)	71	Apr. 6	12 6—12 52	Dublin.
283·1	+22·0	15·6	Terby f. 25	73	May 24	8 40— 8 55	Brussels.
283·7	+22·4	15·3	Green No. 3 (*Ar.* f. 44)	73	May 28	11	Greenwich.
283·7	−22·7	24·3	Cruls X. 1	77	Sept. 12	8 45	Rio de Janeiro.
283·7	−21·6	23·0	Schmidt (*Ar.* f. 8)	62	Sept. 26	8 36	Athens.
284·5	−25·0	18·6	Lohse 12	77	Oct. 15	8 20	Berlin.
284·6	−25·4	17·6	Niesten IV. 2	77	Oct. 20	10 55	Brussels.
286·7	−22·6	24·5	Cruls IX. 1	77	Sept. 10	7 45	Rio de Janeiro.
290·7	+22·2	15·5	Lohse f. 6	73	May 25	10 5	Bothkamp.
291·4	+27·2	11·3	Gledhill (*Ar.* f. 51)	71	May 7	8	Greenwich.
295·9	−24·8	19·0	Niesten III. 6	77	Oct. 13	7 15	Brussels.
297·0	−22·6	24·5	Green 11	77	Sept. 10	11 20	Greenwich.
297·1	−22·6	24·6	Boeddicker II. 1	77	Sept. 8	11 1·5	Berlin.
298·4	−22·5	24·7	Boeddicker I. 2	77	Sept. 6	9 54·6	Berlin.
299·5	+22·0	15·7	Knobel 14	73	May 23	9 0	Greenwich.
300·3	+22·0	15·6	Burton (*Ar.* f. 11)	73	May 24	9	Dublin.
304·4	−22·6	24·6	Boeddicker II. 2	77	Sept. 8	11 31·4	Berlin.
304·4	−25·3	18·0	Niesten IV. 1	77	Oct. 18	11	Brussels.
304·5	+15·8	15·4	Terby f. 15	73	Apr. 13	9 50—10 30	Brussels.
309·8	−22·6	24·6	Dreyer 2	77	Sept. 8	11 0	Greenwich.
310·8	+22·2	15·5	Green No. 4 (*Ar.* f. 15)	73	May 25	11	Greenwich.

Areographical Long. and Lat. of the Centre of the Disk.		Diameter.		Times assigned to the Sketches.				
°	°	″				h m	h m	
253·5	−22·5	15·2	Burton (*Ar.* f. 20)	1873	May 29	9	— 9 15	Dublin.
256·5	−22·8	24·0	Dreyer 5	77	Sept. 15	11 35		Greenwich.
256·7	+16·8	16·0	Lohse f. 1.	73	Apr. 20	11 30		Bothkamp.
257·0	+22·0	15·7	Schmidt (*Ar.* f. 21)	73	May 23	7 41		Athens.
259·8	+27·4	10·9	Wilson (*Ar.* f. 22)	71	May 12	9		Greenwich.
261·6	+16·5	15·8	Terby f. 16	73	Apr. 18	10 5	—10 25	Brussels.
?265·3	−22·7	24·3	Boeddicker V. 1	77	Sept. 12	*circa* 11 16		Berlin.
265·9	+25·9	13·8	Burton (*Ar.* f. 42)	71	Apr. 7	11 39	—12 18	Dublin.
266·5	−22·6	24·5	Green 10	77	Sept. 10	9 15		Greenwich.
266·9	−22·6	24·5	Lohse 2	77	Sept. 10	10 10		Berlin.
267·8	−22·7	24·3	Cruls IX. 2	77	Sept. 12	7 40		Rio de Janeiro.
268·7	−22·7	24·4	Terby 2	77	Sept. 11	10 5	—10 30	Brussels.
269·0	+16·8	16·0	Knobel 1	73	Apr. 20	11 40		Greenwich.
271·7	−22·7	24·4	Niesten I. 3	77	Sept. 11	10 30		Brussels.
271·8	+25·7	14·0	Crossley & Gledhill (*Ar.* f. 18)	71	Apr. 4	11		Greenwich.
272·6	−24·7	24·3	Boeddicker V. 2	77	Sept. 12	11 45·6		Berlin.
274·8	−22·6	24·6	Lohse 1	77	Sept. 8	9 30		Berlin.
275·5	+25·7	14·0	Webb (*Ar.* f. 53)	71	Apr. 4	11 15		Greenwich.
279·4	−22·7	24·3	Dreyer 4	77	Sept. 12	11 20		Greenwich.
280·5	+21·9	15·8	Schmidt (*Ar.* f. 16)	73	May 22	8 41		Athens.

281·1	−25·0	18·6	Niesten III. 8	77	Oct. 15	7 30	Brussels.
282·2	+25·8	13·9	Burton (*Ar.* f. 10)	71	Apr. 6	12 6—12 52	Dublin.
283·1	+22·0	15·6	Terby f. 25	73	May 24	8 40— 8 55	Brussels.
283·7	+22·4	15·3	Green No. 3 (*Ar.* f. 44)	73	May 28	11	Greenwich.
283·7	−22·7	24·3	Cruls X. 1	77	Sept. 12	8 45	Rio de Janeiro.
283·7	−21·6	23·0	Schmidt (*Ar.* f. 8)	62	Sept. 26	8 36	Athens.
284·5	−25·0	18·6	Lohse 12	77	Oct. 15	8 20	Berlin.
284·6	−25·4	17·6	Niesten IV. 2	77	Oct. 20	10 55	Brussels.
286·7	−22·6	24·5	Cruls IX. 1	77	Sept. 10	7 45	Rio de Janeiro.
290·7	+22·2	15·5	Lohse f. 6	73	May 25	10 5	Bothkamp.
291·4	+27·2	11·3	Gledhill (*Ar.* f. 51)	71	May 7	8	Greenwich.
295·9	−24·8	19·0	Niesten III. 6	77	Oct. 13	7 15	Brussels.
297·0	−22·6	24·5	Green 11	77	Sept. 10	11 20	Greenwich.
297·1	−22·6	24·6	Boeddicker II. 1	77	Sept. 8	11 1·5	Berlin.
298·4	−22·5	24·7	Boeddicker I. 2	77	Sept. 6	9 54·6	Berlin.
299·5	+22·0	15·7	Knobel 14	73	May 23	9 0	Greenwich.
300·3	+22·0	15·6	Burton (*Ar.* f. 11)	73	May 24	9	Dublin.
304·4	−22·6	24·6	Boeddicker II. 2	77	Sept. 8	11 31·4	Berlin.
304·4	−25·3	18·0	Niesten IV. 1	77	Oct. 18	11	Brussels.
304·5	+15·8	15·4	Terby f. 15	73	Apr. 13	9 50—10 30	Brussels.
309·8	−22·6	24·6	Dreyer 2	77	Sept. 8	11 0	Greenwich.
310·8	+22·2	15·5	Green No. 4 (*Ar.* f. 15)	73	May 25	11	Greenwich.

Areographical Long. and Lat. of the Centre of the Disk.		Diameter.		Times assigned to the Sketches.				
°	°	″				h m	h m	
? 311·4	−22·6	24·6	Boeddicker III. 1	1877	Sept. 8	*circa* 12		Berlin.
312·4	−24·8	19·0	Terby 15	77	Oct. 13	8 15	— 8 30	Brussels.
314·0	−22·6	24·5	Boeddicker III. 2	77	Sept. 10	13 23·3		Berlin.
314·5	−24·9	18·8	Lohse 11	77	Oct. 14	9 45		Berlin.
314·8	+22·5	15·2	Trouvelot 4	73	May 29	9 0		Cambridge, Mass.
316·4	+21·7	15·9	Terby f. 24	73	May 20	8 30	— 8 45	Brussels.
317·6	−25·0	18·6	Niesten III. 9	77	Oct. 15	10		Brussels.
? 322·0	−22·6	24·6	Dreyer 3	77	Sept. 8	? 11 50	Time uncert.	Greenwich.
322·2	−21·3	22·9	Knott (*Ar.* f. 26)	62	Sept. 23	8 30		Greenwich.
324·2	+25·4	14·2	Webb (*Ar.* f. 13)	71	Mar. 29	11		Greenwich.
325·1	−25·7	18·5	Knott (*Ar.* f. 9)	62	Nov. 3	9		Greenwich.
326·3	−22·6	24·6	Cruls VIII. 2	77	Sept. 8	9 15		Rio de Janeiro.
326·8	+25·4	14·2	Vogel No. 9	71	Mar. 29	11 51		Bothkamp.
327·5	+21·1	16·2	Schmidt (*Ar.* f. 17)	73	May 16	8 15		Athens.
330·8	−22·5	24·6	Dreyer 1	77	Sept. 7	11 50		Greenwich.
331·7	−22·6	24·6	Green	77	Sept. 8	12 30		Greenwich.
332·3	−22·6	24·5	Boeddicker IV. 1	77	Sept. 10	14 38·1		Berlin.
334·5	+22·3	15·4	Trouvelot 3	73	May 23	8 30		Cambridge, Mass.
337·7	+25·2	14·3	Lohse No. 8	71	Mar. 25	10 13		Bothkamp.
340·9	+27·1	11·6	Wilson (*Ar.* f. 14)	71	May 4	8		Greenwich.

343·7	−24·5	19·8	Niesten III. 4	77	Oct.	9	8	Brussels.
344·9	+21·9	15·8	Knobel 13	73	May	22	11 30	Greenwich.
345·2	−24·6	19·6	Lohse 10	77	Oct.	10	9 20	Berlin.
345·5	−24·5	19·8	Terby 14	77	Oct.	9	8 — 8 15	Brussels.
346·0	−22·6	24·6	Weinek 1	77	Sept.	8	14·3	Leipzig.
347·1	−22·5	24·7	Boeddicker I. 1	77	Sept.	5	12 38·1	Berlin.
349·5	−22·7	24·3	Cruls X. 2	77	Sept.	12	13 15 *corr.*	Rio de Janeiro.
350·8	−24·8	19·0	Niesten III. 7	77	Oct.	13	11	Brussels.
353·2	−24·8	19·0	Cruls XIII. 2	77	Oct.	13	8 0	Rio de Janeiro.
354·6	+21·5	16·0	Knobel 11	73	May	19	10 20	Greenwich.
355·8	−24·6	19·6	Dreyer 12	77	Oct.	10	9 10	Greenwich.

When, some years hence, the direction of the axis of *Mars* shall have become better determined than it is at present, these lists will have to be recomputed, and, with the addition of a select number of the old sketches (and, perhaps, with the omission of some of the modern ones), united into one general list. If it is thought desirable, the assumed First Meridian may then be shifted so as to pass through some definite point of Maedler's spot *a*. Owing to some discrepancies in the sketches of 1862, the assumed meridian 0° passes a little to the west of the middle of spot *a*; but the true amount of the difference can only be determined when proper observations shall have been forthcoming.

Observations of Brorsen's Comet, February and March 1879.

By J. Tebbutt, Esq.

Owing to an extraordinary succession of cloudy evenings I have succeeded in obtaining only two determinations of position of Brorsen's comet since the date of my last communication. Each position depends on two ring-comparisons with the $4\frac{1}{2}$-inch Equatoreal. There was no condensation of light in the comet, so that the observation errors will probably prove rather large.

Windsor Mean Time 1879.	App. R.A. of Comet.	Log. for Parallax.	App. N.P.D. of Comet.	Log. for Parallax.	Comp. Star.
d h m s	h m s	+	° ′ ″	+	
Feb. 26 7 49 46	0 49 57·60	8·7454	99 34 50·8	9·7165	B.A.C. 248
Mar. 11 7 18 41	1 30 29·42	8·7299	90 1 17·9	9·7407	Lalande 3045

The adopted mean places of the stars of comparison for 1879·0 and the apparent places for the dates of observation are:—

Comparison Star.	Mean R.A.	App. R.A.	Mean N.P.D.	App. N.P.D.
	h m s	s	° ′ ″	″
B.A.C. 248	0 48 11·45	11·86	99 23 49·5	48·6
Lalande 3045	1 33 12·92	13·37	90 0 7·8	4·7

The comparisons on February 26 are corrected for proper motion and refraction, but the latter correction for the comparisons of March 11 will hardly be appreciable.

Observatory, Windsor, N.S.W.,
1879, *March* 26.

A New Method of controlling the Driving Clock of an Equatoreal.

By R. C. Johnson, Esq.

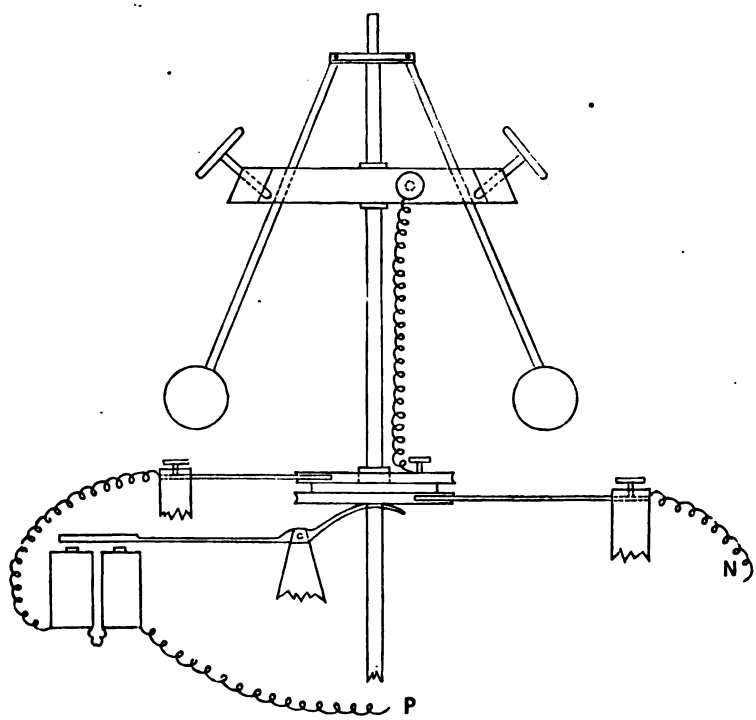
This is a description of an automatic brake to be applied to a rapidly moving part of the mechanism of an ordinary equatoreal Driving Clock whenever the normal velocity is exceeded.

As applied to my Driving Clock belonging to a $9\frac{1}{4}$-inch Reflector, it consists of the following parts:—A frame of brass, slotted so as to enclose, without touching, the centrifugal arms of the governor, is fixed to the upright axis to which these arms are attached, but is insulated from it: in the frame are two brass screws,* which can be regulated so as just to be in contact with the arms when the proper speed has been attained. Two metallic wheels are fixed to the lower part of the axis, the upper of which

* Only one of these need be in use.

is insulated from it, but connected by a wire with the frame in the upper part, and the lower one is in metallic contact with the axis. Two light springs are in contact with these wheels, and an electro-magnetic brake (as shown by the figure) is balanced so as to press lightly on the base of the lower wheel when no current is passing.

Four to eight small-sized Leclanché cells suffice to actuate this brake.



No current can pass until the weighted arms fly out so as to touch one of the screws in the upper frame; electrical contact is then made, the brake acts instantly, and immediately the arms drop an infinitesimal distance and contact is broken: this intermittent action goes on rapidly, and results in an extremely steady speed, the oscillations being so minute that they are barely perceptible, even with a magnifying power of 500 diameters.

I use a driving weight of 40 lb., and find that when this brake is in action 22 lb. can be added without affecting the rate; and I feel sure that by varying the leverage of the brake, or the battery power, or the size of the electro-magnet, that the weight might just as easily be doubled.

This control was devised in order to obviate the necessity of accurately balancing the telescope (when using a spectroscope, for instance) and to prevent the slackening of the clock's speed, which is frequently caused by a rapid fall in the temperature.

The idea was suggested by a description of a control for machinery invented by Mons. Marcel Deprez,* which, however, is exactly the converse of the plan here described.

Of course I do not intend this simple method to compete with the more perfect, but also more expensive, methods devised by Bond and Cooke and Lord Lindsay, but I can confidently recommend it as an excellent and cheap substitute for those who have not very perfect clocks.

Errata in First Melbourne General Catalogue, 1870.

(*Communicated by R. L. J. Ellery, Esq., F.R.S., Director of the Melbourne Observatory.*)

No.	Name.	Place of Error.	Error.	Correction.
194	γ Hydræ	P″	·0034	·0008
358	α Canis Min.	Name	Majoris	Minoris
552	η Octantis	P′	·2099	·1485
		p′	·033	·007
796	κ Trianguli Aus.	P	5·833	5·834
		a	9·0054	9·0056
		b	9·1710	9·1712
		c	0·7659	0·7660
		d	8·9732	8·9734
		N.P.D.	10″·10	40″·10
		m	(−0·25)	(+0·01)
		a′	9·7822	9·7823
895	Octantis, B.A.C. 5976	P′	·8356	·7589
947	α Lyræ	N.P.D.	30′	20′
1067	Octantis, B.A.C. 7020	P	102·365	102·372

1879, *April* 16.

* See *English Mechanic* for March 14, 1879.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXIX. SUPPLEMENTARY NOTICE. No. 9.

On the Values of the Constants in the Equation ${}_rA_r x^{(r)} + {}_rA_{r-1} x^{(r-1)} + \ldots + {}_rA_t x^{(t)} + \ldots + {}_rA_0 - y_x = 0$; *obtained by the method of least squares, from the* $n+1$ *values of* y_x *when* $x = 0, 1, 2, \ldots n$; *n being greater than r.* By C. Carpmael, Esq.

Suppose it known, or assumed, that the value of a quantity y_x (the approximate value of which is known when $x = 0$, and when $x = 1, 2,$ &c. $\ldots n$) may be expressed as the sum of a series of factorials of the form ${}_rA_t x^{(t)}$, where ${}_rA_t$ is the coefficient of $x^{(t)}$ when the highest factorial in the series is $x^{(r)}$.

The object of the following investigation is to determine the values of the coefficients, ${}_rA_r$ &c., which make the sum of the squares of the differences between the given values of y and those obtained from the formula a minimum.*

Now in order that

$$\Sigma_{x=0}^{x=n} ({}_rA_r x^{(r)} + {}_rA_{r-1} x^{(r-1)} + \ldots + {}_rA_t x^{(t)} + \ldots + {}_rA_0 - y_x)^2$$

may be a minimum, ${}_rA_r$ &c. must satisfy simultaneously the $\overline{r+1}$ equations of the form

$${}_rA_r \Sigma_{x=0}^{x=n} x^{(r)} x^{(s)} + {}_rA_{r-1} \Sigma_{x=0}^{x=n} x^{(r-1)} x^{(s)} + \ldots + {}_rA_t \Sigma_{x=0}^{x=n} x^{(t)} x^{(s)} + \ldots$$
$$+ {}_rA_0 \Sigma_{x=0}^{x=n} x^{(s)} - \Sigma_{x=0}^{x=n} x^{(s)} y_x = 0.$$

s having in succession the values $r, r-1, r-2, \ldots, 0$.

The value of ${}_rA_r$ obtained from these equations is a fraction, whose denominator is a determinant of the $\overline{r+1}$ th order, having

$$\Sigma_{x=0}^{x=n} x^{(s)} x^{(t)}$$

* The notation is: $x^{(r)} = x\ (x-1) \ldots (x-r+1)$; $\lfloor r = 1.2.3 \ldots r$; $\Sigma_{x=0}^{x=n} y_x = y_n + y_{n-1} \ldots + y_0$.—Ed.

Areographical Long. and Lat. of the Centre of the Disk.		Diameter.		Times assigned to the Sketches.				
°	°	"				h m	h m	
201·4	+17·7	16·3	Terby f. 18	1873	Apr. 25	10 15	—10 25	Brussels.
207·7	−26·0	16·5	Niesten IV. 11	77	Oct. 26	9 30		Brussels.
209·1	−23·0	23·6	Green 7	77	Sept. 18	10 20		Greenwich.
210·4	+22·7	14·8	Lohse f. 7	73	June 2	9 45		Bothkamp.
211·5	+17·9	16·4	Knobel 4	73	Apr. 26	11 20		Greenwich.
213·0	+22·5	15·1	Green No. 1	73	May 30	7 30		Greenwich.
213·4	−22·2	23·0	Schmidt (*Ar.* f. 39)	62	Oct. 1	7 28		Athens.
215·0	−22·9	23·7	Terby 5	77	Sept. 17	10 15		Brussels.
215·7	−22·4	24·4	Cruls V. 1	77	Aug. 24	17 15	*corr.*	Rio de Janeiro.
218·6	−22·9	23·7	Niesten I. 6	77	Sept. 17	10 30		Brussels.
220·1	+17·3	16·2	Terby f. 17	73	Apr. 23	10 10	—10 40	Brussels.
220·2	−22·9	23·9	Cruls XI. 1	77	Sept. 16	6 50		Rio de Janeiro.
220·5	−23·2	23·1	Weinek 2	77	Sept. 21	13·6		Leipzig.
221·1	+24·0	13·2	Vogel No. 4	71	Feb. 28	11 57		Bothkamp.
221·7	−22·8	24·0	Niesten I. 5	77	Sept. 15	9 30		Brussels.
226·6	−23·0	22·6	Knott (*Ar.* f. 40)	62	Oct. 8	11		Greenwich.
226·8	−23·6	22·1	Cruls XIII. 1	77	Sept. 27	14 0	*corr.*	Rio de Janeiro.
227·4	−25·4	17·6	Niesten IV. 7	77	Oct. 20	7		Brussels.
229·0	−22·9	23·7	Dreyer 7	77	Sept. 17	10 55		Greenwich.
232·2	−25·4	17·6	Niesten IV. 6	77	Oct. 20	7 20		Brussels.

232·3	−23·0	23·6	Green 8	77	Sept. 18	11 45	Greenwich.
232·4	+25·9	13·8	Lohse No. 10	71	Apr. 8	11 23	Bothkamp.
234·5	+22·5	15·2	Terby f. 26	73	May 29	8 30— 8 35	Brussels.
234·7	+22·6	15·0	Knobel 16	73	May 31	9 30	Greenwich.
235·4	+17·3	16·2	Knobel 2	73	Apr. 23	11 40	Greenwich.
236·7	−26·0	16·5	Niesten IV. 8	77	Oct. 26	11 30	Brussels.
236·8	+25·9	13·7	Lohse No. 11	71	Apr. 9	12 17	Bothkamp.
237·1	−25·4	17·6	Niesten IV. 5	77	Oct. 20	7 40	Brussels.
237·2	+26·0	13·6	Lohse No. 12	71	Apr. 10	12 55	Bothkamp.
237·9	−22·8	24·1	Niesten I. 4	77	Sept. 14	10	Brussels.
237·9	−22·9	23·5	Dreyer 6	77	Sept. 16	10 55	Greenwich.
239·9	+22·4	15·3	Green No. 2 (*Ar.* f. 43)	73	May 28	8	Greenwich.
240·9	−22·8	24·1	Terby 3	77	Sept. 14	10 —10 25	Brussels.
241·0	−22·9	23·8	Cruls XI. 2	77	Sept. 16	8 15	Rio de Janeiro.
244·0	+25·8	13·7	Gledhill (*Ar.* f. 52)	71	Apr. 8	11 30	Greenwich.
247·0	+25·8	13·9	Gledhill (*Ar.* f. 41)	71	Apr. 6	10 30	Greenwich.
248·2	−22·7	24·3	Boeddicker IV. 2	77	Sept. 12	10 5·9	Berlin.
248·7	+22·6	15·1	Knobel 15	73	May 30	9 50	Greenwich.
250·4	−22·8	24·0	Green 9	77	Sept. 15	11 10	Greenwich.
250·5	−25·4	17·6	Niesten IV. 4	77	Oct. 20	8 35	Brussels.
251·2	+17·3	16·2	Knobel 3	73	Apr. 23	12 15	Greenwich.
253·3	−25·3	18·0	Niesten IV. 3	77	Oct. 18	7 30	Brussels.

Areographical Long. and Lat. of the Centre of the Disk.		Diameter.		Times assigned to the Sketches.				
°	°	″				h m	h m	
253·5	+22·5	15·2	Burton (*Ar.* f. 20)	1873	May 29	9	— 9 15	Dublin.
256·5	−22·8	24·0	Dreyer 5	77	Sept. 15	11 35		Greenwich.
256·7	+16·8	16·0	Lohse f. 1.	73	Apr. 20	11 30		Bothkamp.
257·0	+22·0	15·7	Schmidt (*Ar.* f. 21)	73	May 23	7 41		Athens.
259·8	+27·4	10·9	Wilson (*Ar.* f. 22)	71	May 12	9		Greenwich.
261·6	+16·5	15·8	Terby f. 16	73	Apr. 18	10 5	—10 25	Brussels.
?265·3	−22·7	24·3	Boeddicker V. 1	77	Sept. 12	*circa* 11 16		Berlin.
265·9	+25·9	13·8	Burton (*Ar.* f. 42)	71	Apr. 7	11 39	—12 18	Dublin.
266·5	−22·6	24·5	Green 10	77	Sept. 10	9 15		Greenwich.
266·9	−22·6	24·5	Lohse 2	77	Sept. 10	10 10		Berlin.
267·8	−22·7	24·3	Cruls IX. 2	77	Sept. 12	7 40		Rio de Janeiro.
268·7	−22·7	24·4	Terby 2	77	Sept. 11	10 5	—10 30	Brussels.
269·0	+16·8	16·0	Knobel 1	73	Apr. 20	11 40		Greenwich.
271·7	−22·7	24·4	Niesten I. 3	77	Sept. 11	10 30		Brussels.
271·8	+25·7	14·0	Crossley & Gledhill (*Ar.* f. 18)	71	Apr. 4	11		Greenwich.
272·6	−24·7	24·3	Boeddicker V. 2	77	Sept. 12	11 45·6		Berlin.
274·8	−22·6	24·6	Lohse 1	77	Sept. 8	9 30		Berlin.
275·5	+25·7	14·0	Webb (*Ar.* f. 53)	71	Apr. 4	11 15		Greenwich.
279·4	−22·7	24·3	Dreyer 4	77	Sept. 12	11 20		Greenwich.
280·5	+21·9	15·8	Schmidt (*Ar.* f. 16)	73	May 22	8 41		Athens.

281·1	−25·0	18·6	Niesten III. 8	77	Oct. 15	7 30	Brussels.
282·2	+25·8	13·9	Burton (*Ar.* f. 10)	71	Apr. 6	12 6–12 52	Dublin.
283·1	+22·0	15·6	Terby f. 25	73	May 24	8 40— 8 55	Brussels.
283·7	+22·4	15·3	Green No. 3 (*Ar.* f. 44)	73	May 28	11	Greenwich.
283·7	−22·7	24·3	Cruls X. 1	77	Sept. 12	8 45	Rio de Janeiro.
283·7	−21·6	23·0	Schmidt (*Ar.* f. 8)	62	Sept. 26	8 36	Athens.
284·5	−25·0	18·6	Lohse 12	77	Oct. 15	8 20	Berlin.
284·6	−25·4	17·6	Niesten IV. 2	77	Oct. 20	10 55	Brussels.
286·7	−22·6	24·5	Cruls IX. 1	77	Sept. 10	7 45	Rio de Janeiro.
290·7	+22·2	15·5	Lohse f. 6	73	May 25	10 5	Bothkamp.
291·4	+27·2	11·3	Gledhill (*Ar.* f. 51)	71	May 7	8	Greenwich.
295·9	−24·8	19·0	Niesten III. 6	77	Oct. 13	7 15	Brussels.
297·0	−22·6	24·5	Green 11	77	Sept. 10	11 20	Greenwich.
297·1	−22·6	24·6	Boeddicker II. 1	77	Sept. 8	11 1·5	Berlin.
298·4	−22·5	24·7	Boeddicker I. 2	77	Sept. 6	9 54·6	Berlin.
299·5	+22·0	15·7	Knobel 14	73	May 23	9 0	Greenwich.
300·3	+22·0	15·6	Burton (*Ar.* f. 11)	73	May 24	9	Dublin.
304·4	−22·6	24·6	Boeddicker II. 2	77	Sept. 8	11 31·4	Berlin.
304·4	−25·3	18·0	Niesten IV. 1	77	Oct. 18	11	Brussels.
304·5	+15·8	15·4	Terby f. 15	73	Apr. 13	9 50—10 30	Brussels.
309·8	−22·6	24·6	Dreyer 2	77	Sept. 8	11 0	Greenwich.
310·8	+22·2	15·5	Green No. 4 (*Ar.* f. 15)	73	May 25	11	Greenwich.

Areographical Long. and Lat. of the Centre of the Disk.		Diameter.		Times assigned to the Sketches.				
°	°	″				h m	h m	
? 311·4	−22·6	24·6	Boeddicker III. 1	1877	Sept. 8	*circa* 12		Berlin.
312·4	−24·8	19·0	Terby 15	77	Oct. 13	8 15	— 8 30	Brussels.
314·0	−22·6	24·5	Boeddicker III. 2	77	Sept. 10	13 23·3		Berlin.
314·5	−24·9	18·8	Lohse 11	77	Oct. 14	9 45		Berlin.
314·8	+22·5	15·2	Trouvelot 4	73	May 29	9 0		Cambridge, Mass.
316·4	+21·7	15·9	Terby f. 24	73	May 20	8 30	— 8 45	Brussels.
317·6	−25·0	18·6	Niesten III. 9	77	Oct. 15	10		Brussels.
? 322·0	−22·6	24·6	Dreyer 3	77	Sept. 8	? 11 50	Time uncert.	Greenwich.
322·2	−21·3	22·9	Knott (*Ar.* f. 26)	62	Sept. 23	8 30		Greenwich.
324·2	+25·4	14·2	Webb (*Ar.* f. 13)	71	Mar. 29	11		Greenwich.
325·1	−25·7	18·5	Knott (*Ar.* f. 9)	62	Nov. 3	9		Greenwich.
326·3	−22·6	24·6	Cruls VIII. 2	77	Sept. 8	9 15		Rio de Janeiro.
326·8	+25·4	14·2	Vogel No. 9	71	Mar. 29	11 51		Bothkamp.
327·5	+21·1	16·2	Schmidt (*Ar.* f. 17)	73	May 16	8 15		Athens.
330·8	−22·5	24·6	Dreyer 1	77	Sept. 7	11 50		Greenwich.
331·7	−22·6	24·6	Green	77	Sept. 8	12 30		Greenwich.
332·3	−22·6	24·5	Boeddicker IV. 1	77	Sept. 10	14 38·1		Berlin.
334·5	+22·3	15·4	Trouvelot 3	73	May 23	8 30		Cambridge, Mass.
337·7	+25·2	14·3	Lohse No. 8	71	Mar. 25	10 13		Bothkamp.
340·9	+27·1	11·6	Wilson (*Ar.* f. 14)	71	May 4	8		Greenwich.

343·7	−24·5	19·8	Niesten III. 4	77	Oct.	9	8	Brussels.
344·9	+21·9	15·8	Knobel 13	73	May	22	11 30	Greenwich.
345·2	−24·6	19·6	Lohse 10	77	Oct.	10	9 20	Berlin.
345·5	−24·5	19·8	Terby 14	77	Oct.	9	8 — 8 15	Brussels.
346·0	−22·6	24·6	Weinek 1	77	Sept.	8	14·3	Leipzig.
347·1	−22·5	24·7	Boeddicker I. 1	77	Sept.	5	12 38·1	Berlin.
349·5	−22·7	24·3	Cruls X. 2	77	Sept.	12	13 15 *corr.*	Rio de Janeiro.
350·8	−24·8	19·0	Niesten III. 7	77	Oct.	13	11	Brussels.
353·2	−24·8	19·0	Cruls XIII. 2	77	Oct.	13	8 0	Rio de Janeiro.
354·6	+21·5	16·0	Knobel 11	73	May	19	10 20	Greenwich.
355·8	−24·6	19·6	Dreyer 12	77	Oct.	10	9 10	Greenwich.

When, some years hence, the direction of the axis of *Mars* shall have become better determined than it is at present, these lists will have to be recomputed, and, with the addition of a select number of the old sketches (and, perhaps, with the omission of some of the modern ones), united into one general list. If it is thought desirable, the assumed First Meridian may then be shifted so as to pass through some definite point of Maedler's spot *a*. Owing to some discrepancies in the sketches of 1862, the assumed meridian 0° passes a little to the west of the middle of spot *a*; but the true amount of the difference can only be determined when proper observations shall have been forthcoming.

$$\begin{vmatrix} 1 & \cdots & 1 \\ r+1 & \cdots & 2r-1 \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ (r+1)^{(r-s-2)} & \cdots & (2r-1)^{(r-s-2)} \\ (r+1)^{(r-s)} & \cdots & (2r-1)^{(r-s)} \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ (r+1)^{(r-1)} & \cdots & (2r-1)^{(r-1)} \end{vmatrix}$$

$$\frac{(-1)^r}{r-s} \quad \text{---------------------------------------}$$

$$\begin{vmatrix} 1 & \cdots & 1 \\ r+1 & \cdots & 2r \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ (r+1)^{(r-s-1)} & \cdots & (2r)^{(r-s-1)} \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ (r+1)^{(r-1)} & \cdots & (2r)^{(r-1)} \end{vmatrix}$$

where the determinants are similar in form to those in (iii) but one order lower, and the missing row in the numerator is now that containing factorials of $\overline{r-s-1}$ factors.

Repeat the reduction in this way $\overline{r-s}$ times, including that already performed, then the value of ${}_rR_s$ will be reduced to the form

$$\begin{vmatrix} r+1 & r+2 & \cdots & r+s \\ (r+1)^{(1)} & (r+2)^{(1)} & \cdots & (r+s)^{(1)} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ (r+1)^{(s)} & (r+2)^{(s)} & \cdots & (r+s)^{(s)} \end{vmatrix}$$

$$\frac{(-1)^r}{\overline{r-s}} \quad \text{---------------------------------------}$$

$$\begin{vmatrix} 1 & 1 & \cdots & 1 \\ r+1 & r+2 & \cdots & r+s+1 \\ (r+1)^{(1)} & (r+2)^{(1)} & \cdots & (r+s+1)^{(1)} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ (r+1)^{(s)} & (r+2)^{(s)} & \cdots & (r+s+1)^{(s)} \end{vmatrix}$$

The determinants have now been reduced $r-s$ orders lower than at first, and the row of the denominator which is missing in the numerator is that in which every constituent is unity.

Taking out the factors in the numerator which occur throughout any column, we get

$$ {}_rR_s = (-1)^r \frac{\lfloor r+s}{\lfloor r \lfloor r-s} \frac{\begin{pmatrix} 1 & \cdots & 1 \\ r & \cdots & r+s-1 \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ r^{(s-1)} & \cdots & (r+s-1)^{(s-1)} \end{pmatrix}}{\begin{pmatrix} 1 & \cdots & 1 \\ r+1 & \cdots & r+s+1 \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ (r+1)^{(s)} & \cdots & (r+s+1)^{(s)} \end{pmatrix}} $$

The row now missing in the numerator is the last, and in the numerator r occurs instead of $r+1$.

Reduce the order of the determinants in the same way as before, s times, we get

$$ {}_rR_s = (-1)^r \frac{\lfloor r+s}{\lfloor r \lfloor s \lfloor r-s}. $$

Substituting this value for ${}_rR_s$ in (ii), we get for the value of ${}_rA_r$

$$ A_r = \Sigma_{s=0}^{s=r} (-1)^{r+s} \frac{\lfloor 2r+1}{(\lfloor r \lfloor s)^2} \frac{\lfloor r+s}{\lfloor r-s} \frac{1}{(n+r+1)^{(r+s+1)}} \Sigma_{x=0}^{x=n} x^{(s)} y_x. \qquad (A) $$

From this formula we can without much labour determine the coefficient, in any numerical example, of the highest factorial in the expression for y.

The values of the remaining coefficients are most easily obtained by an indirect method, as follows:—

Let ${}_rB_\rho$ be the value of ${}_rA_r$ when $x^{(\rho)}$ is substituted for y_x, then

$$ {}_rB_\rho = \Sigma_{s=0}^{s=r} (-1)^{r+s} \frac{\lfloor 2r+1}{(\lfloor r \lfloor s)^2} \frac{\lfloor r+s}{\lfloor r-s} \frac{1}{(n+r+1)^{(r+s+1)}} \Sigma_{x=0}^{x=n} x^{(s)} x^{(\rho)}. $$

Now by aid of the formula

$$ \Delta^{-1} u_x v_x = u_{x-1} \Delta^{-1} v_x - \Delta u_{x-2} \Delta^{-2} v_x + \&c., $$

we have

$$\Sigma_{x=0}^{x=n} x^{\rho} x^{(\rho)} = n^{\rho} \frac{(n+1)^{(\rho+1)}}{\rho+1} - s\,(n-1)^{s-1} \frac{(n+1)^{(\rho+2)}}{(\rho+1)(\rho+2)} + \ldots$$

$$+ (-1)^{p} \frac{s}{s-p} (n-p)^{s-p} \frac{\rho}{\rho+p+1} (n+1)^{(\rho+p+1)} + \&c.$$

Hence ${}_rB_\rho$ may be written in the form

$$\Sigma_{s=r}^{s=r} \frac{2r+1}{(r)^2} \frac{\lfloor r+s}{\lfloor r-s} \frac{1}{(n+r+1)^{(r+s+1)}} \Sigma_{p=0}^{p=s} \frac{\lfloor s}{\lfloor s-p} \frac{n-p}{n-s} \frac{\rho}{\rho+p+1} (n+1)^{(\rho+p+1)} (-1)^{p+r+s};$$

or

$$\Sigma_{s=r}^{s=r} \Sigma_{p=0}^{p=s} (-1)^{p+r+s} \frac{2r+1}{(r)^2} \frac{\lfloor r+s}{\lfloor s} \frac{n-p}{\lfloor r-s} \frac{\rho}{\lfloor s-p} \frac{\lfloor n+1}{\rho+p+1} \frac{}{\lfloor n-\rho-p};$$

or, changing the order of the summations,

$${}_rB_\rho = \Sigma_{p=0}^{p=r} \Sigma_{s=p}^{s=r} (-1)^{p+r+s} \frac{2r+1}{(r)^2} \frac{\lfloor n-p}{n+r+1} \frac{\lfloor \rho}{\rho+p+1} \frac{n+1}{\lfloor n-\rho-p} \frac{\lfloor r+s}{\lfloor s} \frac{}{r-s} \frac{}{s-p}.$$

Now

$$\frac{\lfloor r+s}{\lfloor s} \text{ is } = \text{ coeff. of } x^s \text{ in expansion of } \underline{r}\,(1-x)^{-r-1},$$

and

$$(-1)^{r\pm s} \frac{1}{\lfloor r-s} \frac{}{\lfloor s-p} \text{ is } = \text{ coeff. of } x^{r-s} \text{ in expansion of } \frac{(1-x)^{r-p}}{\lfloor r-p},$$

when s has any value from $s=p$ to $s=r$; therefore

$$\Sigma_{s=p}^{s=r} (-1)^{r+s} \frac{\lfloor r+s}{\lfloor s} \frac{1}{\lfloor r-s} \frac{}{\lfloor s-p}$$

is $=$ coeff. of x^r in expansion of

$$\frac{r}{\lfloor r-p} (1-x)^{-p-1},$$

that is, it is $=$

$$\frac{\lfloor r}{\lfloor r-p} \frac{\lfloor r+p}{\lfloor r} \frac{}{\lfloor p} \quad \text{or} \quad \frac{\lfloor r+p}{\lfloor r-p} \frac{}{\lfloor p}.$$

Hence

$${}_rB_\rho = \Sigma_{p=0}^{p=r} (-1)^{p} \frac{\lfloor 2r+1}{(\lfloor r)^2} \frac{\lfloor \rho}{\lfloor n+r+1} \frac{n+1}{\lfloor \rho+p+1} \frac{\lfloor n-p}{\lfloor n-\rho-p} \frac{\lfloor r+p}{\lfloor r-p} \frac{}{\lfloor p},$$

which may be written

$${}_rB_\rho = \frac{2r+1}{(\lfloor r)^2} \frac{n+1}{\lfloor n+r+1} \frac{\rho}{} \left(1 - \frac{E'}{E}\right)^{r} n^{(\rho)} (r+1)^{(-\rho+r-1)},$$

where

E′ applies only to $(r+1)^{(-\rho+r-1)}$ and $\mathrm{E}'(r+1)^{(-\rho+r-1)} = (r+2)^{(-\rho+r-1)}$,

and

E applies only to $n^{(\rho)}$ and $\mathrm{E}\,n^{(\rho)} = (n+1)^{(\rho)}$.

Hence

$$ {}_rB_\rho = \frac{\lfloor 2r+1 \rfloor \lfloor n+1 \rfloor \rho}{(\lfloor r \rfloor)^2 \lfloor n+r+1 \rfloor} \left(\frac{\Delta - \Delta'}{\mathrm{E}}\right)^r n^{(\rho)} (r+1)^{(-\rho+r-1)}, $$

$$ = \frac{\lfloor 2r+1 \rfloor \lfloor n+1 \rfloor \rho}{(\lfloor r \rfloor)^2 \lfloor n+r+1 \rfloor} \Sigma_{p=0}^{p=r} \frac{\lfloor r \, (-1)^{r-p}}{\lfloor p \rfloor \lfloor r-p \rfloor} \Delta^p (n-r)^{(\rho)} \Delta'^{r-p} (r+1)^{(-\rho+r-1)}, $$

$$ = \frac{\lfloor 2r+1 \rfloor \lfloor n+1 \rfloor \rho}{(\lfloor r \rfloor)^2 \lfloor n+r+1 \rfloor} \Sigma_{p=0}^{p=r} \frac{\lfloor r}{\lfloor p \rfloor \lfloor r-p} \rho^{(p)} (n-r)^{(\rho-p)} \frac{\lfloor \rho-p}{\lfloor \rho-r} (r+1)^{(-\rho+p-1)}, $$

$$ = \frac{\lfloor 2r+1 \rfloor \lfloor n-r}{\lfloor n+r+1 \rfloor \lfloor \rho-r} \left(\frac{\rho}{r}\right)^2 \Sigma_{p=0}^{p=r} \frac{\lfloor n+1}{\lfloor n-r-\rho+p \rfloor \lfloor r+\rho-p+1} \frac{\lfloor r}{\lfloor p \rfloor \lfloor r-p}. $$

Now

$$ \frac{\lfloor n+1}{\lfloor n-r-\rho+p \rfloor \lfloor r+\rho-p+1} \text{ is } = \text{ coeff. of } x^{r+\rho-p+1} \text{ in expansion of } (1+x)^{n+1}, $$

and

$$ \frac{\lfloor r}{\lfloor p \rfloor \lfloor r-p} \text{ is } = \text{ coeff. of } x^p \text{ in expansion of } (1+x)^r; $$

therefore

$$ \Sigma_{p=0}^{p=r} \frac{\lfloor n+1 \rfloor r}{\lfloor n-r-\rho+p \rfloor \lfloor r+\rho-p+1 \rfloor p \rfloor r-p} $$

is = coeff. of $x^{r+\rho+1}$ in the expansion of $\overline{1+x}^{n+r+1}$, and is therefore

$$ = \frac{\lfloor n+r+1}{\lfloor r+\rho+1 \rfloor \lfloor n-\rho}; $$

Hence

$$ {}_rB_\rho = \frac{\lfloor n-r \rfloor 2r+1}{\lfloor r+\rho+1 \rfloor \lfloor n-\rho \rfloor \rho-r} \left(\frac{\rho}{r}\right)^2, $$

$$ = \frac{\overline{(n-r)}^{(\rho-r)}}{(r+\rho+1)^{(\rho-r)}} \frac{\{\rho^{(\rho-r)}\}^2}{\lfloor \rho-r}. \qquad \text{(iv)} $$

Now the original equations for finding ${}_rA_r$, ${}_rA_{r-1}$, &c. may be written

$$ {}_rA_t \Sigma_{x=0}^{x=n} x^{(t)} x^{(s)} + {}_rA_{t-1} \Sigma_{x=0}^{x=n} x^{(t-1)} x^{(s)} \ldots $$

$$ + {}_rA_0 \Sigma_{x=0}^{x=n} x^{(s)} - \Sigma_{x=0}^{x=n} x^{(s)} (y_x - {}_rA_r x^{(r)} - \ldots - {}_rA_{t+1} x^{(t+1)}) = 0; $$

so that when

$$ {}_rA_r, \ {}_rA_{r-1} \ldots {}_rA_{t+1} $$

have been determined, ${}_rA_t$ may be obtained in the manner that ${}_rA_r$ was, but with

$$ y_x - {}_rA_r x^{(r)} - \ldots - {}_rA_{t+1} x^{(t+1)} $$

written for y_x.

Hence by (A)

$$ {}_rA_t = \Sigma_{s=0}^{s=t} (-1)^{s+t} \frac{\lfloor 2t+1}{(\lfloor t)^2} \frac{\lfloor t+s}{\lfloor t-s} \frac{1}{(n+t+1)^{(s+t+1)}} \times $$

$$ \Sigma_{x=0}^{x=n} x^{(s)} \{ y_x - {}_rA_r x^{(r)} - \ldots - {}_rA_p x^{(p)} - \ldots - {}_rA_{t+1} x^{(t+1)} \} $$

$$ = {}_tA_t - {}_tB_r \cdot {}_rA_r - {}_tB_{r-1} \cdot {}_rA_{r-1} - \ldots - {}_tB_p \cdot {}_rA_p - \ldots {}_tB_{t+1} \cdot {}_rA_{t+1} $$

$$ = {}_tA_t - \Sigma_{p=t+1}^{p=r} {}_tB_p \cdot {}_rA_p, $$

$$ = {}_tA_t - \Sigma_{p=t+1}^{p=r} \frac{(n-t)^{(p-t)} \{ p^{(p-t)} \}^2}{(t+p+1)^{(p-t)} \lfloor p-t} {}_rA_p. \qquad (v) $$

Suppose $t = r-1$, then by (v)

$$ {}_rA_{r-1} = {}_{r-1}A_{r-1} - \frac{n-r+1}{2r} r^2 \, {}_rA_r. $$

Similarly, if in (v) t be put equal to $r-2$, we get

$$ {}_rA_{r-2} = {}_{r-2}A_{r-2} - \frac{n-r+2}{2r-2} (r-1)^2 \left\{ {}_{r-1}A_{r-1} - \frac{n-r+1}{2r} r^2 \, {}_rA_r \right\} $$

$$ - \frac{(n-r+2)^{(2)}}{(2r-1)^{(2)}} \frac{\{r^{(2)}\}^2}{\lfloor 2} {}_rA_r, $$

$$ = {}_{r-2}A_{r-2} - \frac{n-r+2}{2(r-1)} (r-1)^2 \, {}_{r-1}A_{r-1} + \frac{(n-r+2)^{(2)} \{r^{(2)}\}^2}{2(2r)^{(2)}} {}_rA_r. $$

In the same way if t be put equal to $x-3$ in (v), it will be found that the resulting equation may be reduced to the form

$$ {}_rA_{r-3} = {}_{r-3}A_{r-3} - \frac{n-r+3}{2r-4} (r-2)^2 \, {}_{r-3}A_{r-3} $$

$$ + \frac{(n-r+3)^{(2)}}{\lfloor 2} \frac{\{(r-1)^{(2)}\}^2}{(2r-2)^{(2)}} {}_{r-1}A_{r-1} - \frac{(n-r+3)^{(3)} \{r^{(3)}\}^2}{\lfloor 3 \, (2r)^{(3)}} {}_rA_r. $$

We see then that as far as ${}_rA_{r-3}$ the value of ${}_rA_s$ is of the form

$$\Sigma_{t=s}^{t=r}(-1)^{s+t}\frac{(n-s)^{(t-s)}\{\lfloor(t-s)\}^2}{(2t)^{(t-s)}\,\lfloor t-s}\,{}_tA_t. \qquad (B)$$

Let us assume that all the coefficients ${}_rA_{r-1}, {}_rA_{r-2}\ldots{}_rA_s$ are of this form; we will prove that ${}_rA_{s-1}$ must also be of this form.

For by (v)

$${}_rA_{s-1} = {}_{s-1}A_{s-1} - \Sigma_{p=s}^{p=r}\frac{(n-s+1)^{(p-s+1)}\{\lfloor p^{(p-s+1)}\}^2}{(s+p)^{(p-s+1)}\,\lfloor p-s+1}\,{}_rA_p$$

$$= {}_{s-1}A_{s-1} - \Sigma_{p=s}^{p=r}\frac{(n-s+1)^{(p-s+1)}\{\lfloor p^{(p-s+1)}\}^2}{(s+p)^{(p-s+1)}\,\lfloor p-s+1}\,\Sigma_{t=p}^{t=r}(-1)^{p+t}\frac{(n-p)^{(t-p)}\{\lfloor t^{(t-p)}\}^2}{(2t)^{(t-p)}\,\lfloor t-p}\,{}_tA_t$$

(for, by hypothesis, B holds for all values of from s to r); therefore

$${}_rA_{s-1} = {}_{s-1}A_{s-1} - \Sigma_{p=s}^{p=r}\,\Sigma_{t=p}^{t=r}(-1)^{p+t}\frac{(n-s+1)^{(t-s+1)}\{\lfloor t^{(t-s+1)}\}^2}{(2t)^{(t-p)}\,\lfloor t-p\;(s+p)^{(p-s+1)}\,\lfloor p-s+1}\,{}_tA_t;$$

or, changing the order of the summations,

$${}_rA_{s-1} = {}_{s-1}A_{s-1} - \Sigma_{t=s}^{t=r}\,\Sigma_{p=s}^{p=t}(-1)^{p+t}\frac{(n-s+1)^{(t-s+1)}\{\lfloor t^{(t-s+1)}\}^2}{(2t)^{(t-p)}\,\lfloor t-p\;(s+p)^{(p-s+1)}\,\lfloor p-s+1}\,{}_tA_t.$$

Now

$$\frac{\lfloor t-s+1}{\lfloor t-p\;\lfloor p-s+1}\text{ is = coeff. of } x^{t-p}\text{ in expansion of } (1+x)^{t-s+1},$$

and

$$(-1)^{p+s}\frac{\lfloor t+p}{\lfloor t-s\;\lfloor p+s}\text{ is = coeff. of } x^{p+s}\text{ in expansion of } (1+x)^{-t+s-1};$$

Hence

$$\Sigma_{p=s-1}^{p=t}(-1)^{p+s}\frac{\lfloor t-s+1}{\lfloor t-p\;\lfloor p-s+1}\,\frac{\lfloor t+p}{\lfloor t-s\;\lfloor p+s}$$

is equal to the coefficient of x^{t+s} in the expansion of $(1+x)^0$ and is therefore zero. Hence

$$\Sigma_{p=s}^{p=t}(-1)^{p+s}\frac{\lfloor t+p}{\lfloor t-p\;\lfloor p-s+1\;\lfloor p+s} = \frac{\lfloor t+s-1}{\lfloor t-s+1\;\lfloor 2s-1};$$

or, finally,

$${}_rA_{s-1} = {}_{s-1}A_{s-1} - \Sigma_{t=s}^{t=r}(-1)^{s+t}\frac{(n-s+1)^{(t-s+1)}\{\lfloor t^{(t-s+1)}\}^2}{\lfloor 2t}\,\frac{\lfloor 2s-1}{\lfloor t-s+1\;\lfloor 2s-1}\,\frac{\lfloor t+s-1}{\lfloor 2s-1}\,{}_tA_t,$$

$$= \Sigma_{t=s-1}^{t=r}(-1)^{s+t-1}\frac{(n-s+1)^{(t-s+1)}\{\lfloor t^{(t-s+1)}\}^2}{(2t)^{t-s+1}\,\lfloor t-s+1}\,{}_tA_t,$$

which is of the form (B) with $s-1$ in place of s.

But ${}_rA_{r-1}$, ${}_rA_{r-2}$ have been already shown to be of the form (B), so therefore is ${}_rA_{r-3}$, and so then ${}_rA_{r-4}$ &c. Hence, for all values of s from $s=0$ to $s=r-1$, ${}_rA_s$ is of the form given by (B).

The result of the foregoing investigation may be thus stated: If ${}_rA_s$ be the coefficient of $x^{(s)}$ obtained, by the method of least squares, from the $n+1$ values of y_x when $x=0, 1, 2, \ldots n$, n being greater than r, and y_x being of the form

$${}_rA_r\,x^{(r)} + {}_rA_{r-1}\,x^{(r-1)} + \ldots + {}_rA_s\,x^{(s)} + \ldots + {}_rA_0;$$

then

$$A_s = \Sigma_{t=s}^{t=r} (-1)^{t+s} \frac{(n-s)^{(t-s)}\{t^{(t-s)}\}^2}{(2t)^{(t-s)}\,\lfloor t-s} \,{}_tA_t, \qquad \text{(B)}$$

where

$${}_tA_t = \Sigma_{\rho=0}^{\rho=t} (-1)^{\rho+t} \frac{2t+1}{(\underline{t-\rho})^2} \frac{(t+\rho)^{(2\rho)}}{(n+t+1)^{(t+\rho+1)}} \Sigma_{x=0}^{x=n} x^{(\rho)}\, y_x. \qquad \text{(A)}$$

The following are the values of the constants, calculated from these formulæ, as far as they are required if fifth differences are assumed to be constant.

$$ {}_0A_0 = \frac{1}{n+1} \Sigma_{x=0}^{x=n} y_x. $$

$$ {}_1A_1 = \frac{-6}{(n+2)(n+1)} \Sigma_{x=0}^{x=n} y_x + \frac{12}{(n+2)(n+1)n} \Sigma_{x=0}^{x=n} x\, y_x. $$

$$ {}_2A_2 = \frac{30}{(n+3)(n+2)(n+1)} \Sigma_{0}^{x=n} y_x - \frac{180}{(n+3)(n+2)(n+1)n} \Sigma_{x=0}^{x=n} x\, y_x + \frac{180}{(n+3)(n+2)\ldots(n-1)} \Sigma_{x=0}^{x=n} x(x-1)\, y_x. $$

$$ {}_3A_3 = \frac{-140}{(n+4)(n+3)\ldots(n+1)} \Sigma_{x=0}^{x=n} y_x + \frac{1680}{(n+4)(n+3)\ldots n} \Sigma_{x=0}^{x=n} x\, y_x - \frac{4200}{(n+4)(n+3)\ldots(n-1)} \Sigma_{x=0}^{x=n} x(x-1)\, y_x + \frac{2800}{(n+4)(n+3)\ldots(n-2)} \Sigma_{x=0}^{x=n} x(x-1)(x-2)\, y_x. $$

$$ {}_4A_4 = \frac{630}{(n+5)(n+4)\ldots(n+1)} \Sigma_{x=0}^{x=n} y_x - \frac{12600}{(n+5)(n+4)\ldots n} \Sigma_{x=0}^{x=n} x\, y_x + \frac{56700}{(n+5)(n+4)\ldots(n-1)} \Sigma_{x=0}^{x=n} x(x-1)\, y_x - \frac{88200}{(n+5)(n+4)\ldots(n-2)} \Sigma_{x=0}^{x=n} x(x-1)(x-2)\, y_x + \frac{44100}{(n+5)(n+4)\ldots(n-3)} \Sigma_{x=0}^{x=n} x(x-1)(x-2)(x-3)\, y_x. $$

$$ {}_5A_5 = \frac{-2772}{(n+6)(n+5)\ldots(n+1)} \Sigma_{x=0}^{x=n} y_x + \frac{83160}{(n-6)(n+5)\ldots n} \Sigma_{x=0}^{x=n} x\, y_x - \frac{582120}{(n+6)(n+5)\ldots(n-1)} \Sigma_{x=0}^{x=n} x(x-1)\, y_x + \frac{1552320}{(n+6)(n+5)\ldots(n-2)} \Sigma_{x=0}^{x=n} x(x-1)(x-2)\, y_x - \frac{1746360}{(n+6)(n+5)\ldots(n-3)} \Sigma_{x=0}^{x=n} x(x-1)(x-2)(x-3)\, y_x + \frac{698544}{(n+6)(n+5)\ldots(n-4)} \Sigma_{x=0}^{x=n} x(x-1)(x-2)(x-3)(x-4)\, y_x. $$

$$
\begin{aligned}
{}_{n}A_0 &= {}_{n-1}A_0 - \frac{n}{2}\,{}_{n-1}A_1 + \frac{n(n-1)}{6}\,{}_{n-2}A_2 - \frac{n(n-1)(n-2)}{20}\,{}_{n-3}A_3 + \frac{n(n-1)(n-2)(n-3)}{70}\,{}_{n-4}A_4 - \frac{n(n-1)(n-2)(n-3)(n-4)}{252}\,{}_{n-5}A_5 + \&c.\\
{}_{n}A_1 &= {}_{n-1}A_1 \quad -(n-1)\,{}_{n-2}A_2 + \frac{3}{5}(n-1)(n-2)\,{}_{n-3}A_3 - \frac{2}{7}(n-1)(n-2)(n-3)\,{}_{n-4}A_4 + \frac{5}{42}(n-1)(n-2)(n-3)(n-4)\,{}_{n-5}A_5 - \&c.\\
{}_{n}A_2 &= \qquad\qquad {}_{n-2}A_2 \quad -\frac{3}{2}(n-2)\,{}_{n-3}A_3 \quad +\frac{9}{7}(n-2)(n-3)\,{}_{n-4}A_4 \quad -\frac{5}{6}(n-2)(n-3)(n-4)\,{}_{n-5}A_5 + \&c.\\
{}_{n}A_3 &= \qquad\qquad\qquad\qquad {}_{n-3}A_3 \quad -2(n-3)\,{}_{n-4}A_4 \quad +\frac{20}{9}(n-3)(n-4)\,{}_{n-5}A_5 - \&c.\\
{}_{n}A_4 &= \qquad\qquad\qquad\qquad\qquad\qquad {}_{n-4}A_4 \quad -\frac{5}{2}(n-4)\,{}_{n-5}A_5 + \&c.
\end{aligned}
$$

If fourth differences are assumed constant, ${}_5A_5$ must be put equal to zero; if third differences are taken as constant, ${}_4A_4$ and ${}_5A_5$ must be put equal to zero; and so on.

In employing these formulæ, it will generally save labour if we subtract from each of the quantities y_x the quantity given by the formula

$$C_r x^{(r)} + C_{r-1} x^{(r-1)} + \ldots + C_s x^{(s)} + \ldots + C_0,$$

where C_r, C_{r-1}, ... C_0 are so chosen as to make

$$y_x - (C_r x^{(r)} + C_{r-1} x^{(r-1)} + \ldots + C_0) = 0$$

for all values of x from $x = n-r$ to $x = n$. Thus all the values of y_x for which the coefficient is large will vanish, and the other values will also, as a rule, be very much diminished. The formulæ (A) and (B) may then be employed, using the remainders, after subtraction, instead of the original values of y_x; and if ${}_rA'_s$ is one of the coefficients so determined, the coefficient in the original value of y_x will be

$$C_s + {}_rA'_s.$$

The above investigation may also be modified, so as to apply to the case when the coefficients in the value for y_x are known to be connected by one or more linear relations, and also for approximating to the values when the relations are not linear.

For, suppose it known that

$$a_r \cdot {}_rA_r + a_{r-1} \cdot {}_rA_{r-1} + \ldots + a_\rho \cdot {}_rA_\rho + \ldots + a_0 \cdot {}_rA_0 + q = 0, \qquad \text{(vi)}$$

we must make

$$\Sigma_{x=0}^{x=n} ({}_rA_r x^{(r)} + {}_rA_{r-1} x^{(r-1)} + \ldots + {}_rA_\rho x^{(\rho)} + \ldots + {}_rA_0 - y_x)^2$$

$$- \lambda (a_r \cdot {}_rA_r + a_{r-1} \cdot {}_rA_{r-1} + \ldots + a_\rho \cdot {}_rA_\rho + \ldots + a_0 \cdot {}_rA_0 + q)$$

a minimum.

The resulting equations are of the same form as before, except that now

$$\lambda a_\rho + \Sigma_{x=0}^{x=n} x^{(\rho)} y_x$$

occurs instead of

$$\Sigma_{x=0}^{x=n} x^{(\rho)} y_x,$$

ρ having any value from 0 to r.

Replacing

$$\Sigma_{x=0}^{x=n} x^\rho y_x \text{ by } \lambda a_\rho + \Sigma_{x=0}^{x=n} x^{(\rho)} y_x$$

in the solution, we get

$$,A_s = \sum_{\rho=0}^{\rho=s} (-1)^{\rho} \frac{2l+1}{(l-\rho)!\,\rho!} \frac{(s-\rho)!}{(n+l+1)^{s-\rho+1}} \{\lambda\, a_\rho + \sum_{\sigma=0}^{\sigma=\rho} z^{\rho-\sigma}\, y_\sigma\}; \qquad \text{(viii)}$$

whence $,A_s$ &c. may be determined in terms of λ. The value of λ must then be determined, so that (vi) is satisfied; and this value must then be substituted in the expressions for $,A_s$ &c.

If the relation be not linear, suppose $\phi\,(,A_r, ,A_{r-1},$ &c.) be the relation.

Let $,A'_r, ,A'_{r-1},$ &c. be the values of the constants found by means of (A) and (B) without reference to the given relation. Suppose $,A_r = ,A'_r + \delta\,,A'_r$ &c., then

$$\phi\,(,A'_r + \delta\,,A'_r, ,A'_{r-1} + \delta\,,A'_{r-1},\ \&c.) = 0;$$

therefore

$$\phi\,(,A'_r, ,A'_{r-1},\ \&c.) + \delta\,,A'_r \frac{d\phi}{d\,,A'_r} + \delta\,,A'_{r-1} \frac{d\phi}{d\,,A'_{r-1}} + \&c. = 0,$$

or

$$,A_r \frac{d\phi}{d\,,A'_r} + ,A_{r-1} \frac{d\phi}{d\,,A'_{r-1}} + \ldots + \phi\,(,A'_r, ,A'_{r-1},\ \&c.) - ,A'_r \frac{d\phi}{d\,,A'_r} - ,A'_{r-1} \frac{d\phi}{d\,,A'_{r-1}} - \&c. = 0.$$

If we suppose that $\delta\,,A$, &c. are so small that their squares and products may be neglected, then $\frac{d\phi}{d\,,A'_r}$ &c. may be treated as constants; the relation will now be of the form (vi) and we may find as above the values of $,A_r, ,A_{r-1},$ &c.

Meteorological Office, Toronto, Canada,
1879, *April* 30.

Royal Observatory, Greenwich,
1879, *July* 29.

It is known generally to the Society that meridional observations on a comprehensive scale are carried on at the Royal Observatory with unceasing regularity; but it is not so generally known that a considerable number of extrameridional or irregular observations have accumulated during my superintendence of the Observatory.

I have thought, therefore, that I might with propriety lay before the Society an arranged list of observations of the last-mentioned classes, nearly the whole of which are included in the annual volumes of *Greenwich Observations*.

G. B. AIRY.

Index to the Records of occasional Observations and Calculations made at the Royal Observatory, Greenwich, and to other miscellaneous Papers connected with that Institution, not comprehended in the ordinary routine of the Observatory, but printed in the Annual Volumes of the Greenwich Observations, from 1836, *January, to* 1875, *December; with List of other Publications of the Royal Observatory.*

List of Subjects of the Papers.

I. Regulations of the Royal Observatory.
II. Plans of the Buildings and Grounds.
III. Descriptions of Instruments.
IV. Auxiliary Tables and New Methods.
V. Results of Earlier Observations.
VI. Catalogues of Principal Stars.
VII. Observations with the Water-Telescope.
VIII. Measures of Double Stars with the Double-image Micrometer.
IX. Observations for a Star's Proper Motion and Parallax.
X. Variations of Brightness and Spectroscopy of Stars.
XI. Micrometric Observations of Solar Eclipses, with complete Reductions.
XII. Observations of Lunar Eclipses.
XIII. Comparisons of Lunar Tables with Observations.
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XXX. Reductions of Modern Magnetic Observations.
XXXI. Barometric Variations.
XXXII. Observations of Thermometers sunk deep in the ground.
XXXIII. Observations of an Earthquake.

The following account of the routine system of the Royal Observatory, commencing from 1836, may be conveniently premised to the Index.

The meridional astronomical observations were made from 1836 to 1850, with Troughton's Transit and Troughton's and

Jones's Circles; and from the beginning of 1851 with the Transit-Circle.

The observations of γ *Draconis* were made with Troughton's Zenith-Tube from 1836 to 1848, and with the Reflex Zenith-Tube from 1851 (first printed in the volume for 1852).

The Altazimuth observations began in May 1847. Observations with the South-east Equatoreal began in 1860.

Meridional and Altazimuth observations, occultations of stars, &c. by the Moon, and phenomena of *Jupiter's* satellites, are completely reduced as far as possible; each in the volume of *Observations* for its year.

The magnetical and meteorological observations from 1843 to 1847 were printed in separate annual volumes. From 1848 they are printed (in a less extended form) in the *Greenwich Observations.*

Reports on trials of chronometers began in 1841.

Reports to the Board of Visitors began in 1836, and were first printed in the *Observations* 1838.

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	III.—Descriptions of Instruments.
...	(The description and the theory of the double-image micrometer are given: for the first form, in the Royal Astronomical Society's *Memoirs*, volume xv., 1845; and for the second or Valz's form, in the *Monthly Notices*, 1850, June 14.)
1847.	(Introduction). Description of the Altazimuth.
1852.	Description of the Transit-Circle.
1854.	Description of the Reflex Zenith-Tube.
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1867.	Description of the Altazimuth. (Reprint.)
1867.	Description of the Transit-Circle. (Reprint.)
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	IV.—Auxiliary Tables and New Methods.
1836.	Bessel's Refraction Tables, in altered form.
1836.	Factors for converting Errors of R.A. and N.P.D. into Errors of Longitude and E. N.P.D.
1837.	Logarithms of Sines and Cosines to every ten seconds of time through the twenty-four hours.
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...	(The method of computing star corrections without use of algebraic signs is given in the Royal Astronomical Society's *Memoirs*, vol. xvi., 1847.)

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1847. Repetition of the method above mentioned.
1847. Day numbers for the application of that method, from 1849 to 1860. (For subsequent years these numbers are given in the *Nautical Almanac.*)
1853. Bessel's Refraction Tables, modified and expanded.
1854. Factors for converting Errors of Azimuth and Zenith Distance into Errors of R.A. and N.P.D.
... (The method of computing interpolations to the second order without changes of algebraic signs is given in the *Monthly Notices*, 1866, April 13.)

V.—Results of Earlier Observations.

1851. Results of the observations of the principal stars made and reduced by Dr. Maskelyne: including determinations of the Equinoxes, of the R.A. of the principal stars, of the Z.D. of γ *Draconis* with Zenith Sector and Quadrant, and of other principal stars with Quadrant, 1765 to 1811. (From Dr. Maskelyne's manuscripts.)

VI.—Catalogues of Principal Stars.

1842. Catalogue of 1439 stars for 1840.
1847. Catalogue of 2156 stars for 1840 and for 1845. (Twelve-year Catalogue.)
1854. Catalogue of 1576 stars for 1850. (Six-year Catalogue.)
1856. Corrections of Secular Variations in the two last-mentioned Catalogues.
1862. Catalogue of 2022 stars for 1860. (First Seven-year Catalogue.)
1868. Catalogue of 2760 stars for 1864. (Second Seven-year Catalogue.)

VII.—Observations with the Water-Telescope.

1871. Observations of Z.D. of γ *Draconis* with the Water-Telescope.
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1848. Observations of the Lunar Eclipses, 1848, March 19 and Sept. 12.
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1863. Observations of the Lunar Eclipse, 1863, June 1.

XIII.—Comparisons of Lunar Tables with Observations.

1856. Results of Lunar Observations, with corrected parallax, 1852 to 1855. (In continuation of the Great Lunar Reductions.)
1859. Comparison of observed places of the Moon with Burckhardt's and Hansen's Tables, 1847 to 1858.

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(These Observations were made with the N.E. Equatoreal at the hour when the Moon was full in right ascension, with the telescope fixed in hour angle, in which state the duration of transit does not differ by $\frac{1}{20000}$ part from that on the meridian.)

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1862. Abstracts of the Magnetic Observations made on Days of Great Magnetic Disturbance, 1841–1857.
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1867. Diagram of Barometric Variations, 1867, October 26 to December 11.

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1860. Reduction by Professor Everett of the Observations of the Deep-sunk Thermometers, 1846-1859.

XXXIII.—Observations of an Earthquake.

1863. Observations of the Earthquake of 1863, October 5.

The following works have been issued from the Royal Observatory, but are not bound as Appendixes to the *Greenwich Observations*:—

Eiffe and Molyneux on Chronometers.
Groombridge's Catalogue of Stars.
Planetary Reductions, 1750 to 1830.
Lunar Reductions, 1750 to 1830 (two volumes).
" " 1831 to 1851 (one volume).
Reduction of Fallows' Observations at the Cape of Good Hope.
Report on the Telescopic Observations of the Transit of *Venus*, 1874.
Reduction of Greenwich Meteorological Observations, viz.:—
Barometer, 1854-1873;
Air and Moisture Thermometers, 1849–1868.
Earth Thermometers, 1847–1873.

On the Apparent Colours of Mars and Saturn, as seen at their approach on 1879, June 29, observed at Glasgow, Missouri, United States.

(In a letter from Professor C. W. Pritchett, Superintendent of the Morrison Observatory, Glasgow, to the Astronomer Royal, dated 1879, July 29.)

1879, June 29, Glasgow mean astronomical time.

Lat. 39° 16 16″·75; Long. from Greenwich 6ʰ 11ᵐ 18ˢ·9.

14ʰ·5—15ʰ. Spent some time in looking at the planets *Saturn* and *Mars* in their very near approach. In the finder of 3½ inches aperture both appeared at once—*Mars* with his usual *ruddy* glow and *Saturn* tinged with a *greenish* hue, which was more and more manifested to be in great part *subjective*, or the *effect of contrast*. In the large telescope, with a micrometer eye-piece of 150, they could not both be seen at once. A separate examination showed *Saturn* with his ring very distinct, three satellites east and south, and one north and west. *Mars* was gibbous and well defined, with his fiery red glare on the illuminated side, and a tinge of green on the defective limb. Always, after looking at *Mars* for some minutes, when the eye was nearly turned on *Saturn*, a reddish tinge was observed which gradually disappeared, showing (I think) that the overmastering power of the light of *Mars* caused such an impression on the optic nerve as to last long enough to produce a purely subjective effect.

Next, a low power eye-piece, of 50, was screwed into the tube; and both planets were readily brought into the same field. The effect of colours then became more apparent. The illuminated surface of *Mars* was clearly defined and ruddy, while *Saturn* showed his usual dull white light; but whenever the eye passed rapidly from *Mars* to *Saturn*, the latter (especially near the centre of the disk) always showed for a few seconds a decidedly reddish tint. It was a rare and grand sight to have both these planets in the same field with a fine objective of 12¼ inches, and I parted with the view with reluctance as one I may never have again. The planets were afterwards examined under an eye-piece of 275. As the morning was fine they presented a splendid appearance. They were now so far out of the field as to produce no *subjective* effect as before. No measures were attempted, as my hand and arm were disabled. Arrangements were made to examine the planets on the morning of June 30, M. Ast. Time, but clouds prevented.

Note on the Transit of the Earth and Moon across the Sun's Disk as seen from Mars on November 12, 1879, and on some kindred Phenomena. By A. Marth, Esq.

At the meeting of the Society in November last I mentioned that on the day of the next opposition of the planet *Mars*, the Earth and Moon, as seen from *Mars*, would cross the Sun's disk, a phenomenon which had not happened since the year 1800, and I stated the chief circumstances connected with the case. The following data will sufficiently indicate the course of the two bodies across the disk:—

Ingress.			Egress.		
1879 Nov. 12. G.M.T. h m	Pos. angle. °		G.M.T. h m	Pos. angle. °	
1 49	125·7	external contact of ☾	9 40	225·3	internal contact of ☾
1 55	126·4	internal „ „	9 46	226·1	external „ „
4 16	123·3	external „ ♂	11 39	225·9	internal „ ♂
4 37	125·9	internal „ „	12 0	228·5	external „ „

The apparent radius of the Sun's disk may be taken to be 650″·5, that of the Earth 18″·1, that of the Moon 4″·9. The position-angles are reckoned from the point of the Sun's disk in the direction of the north pole of the orbit of *Mars*.

The last occasion when the Earth and Moon crossed the Sun's disk for *Mars* occurred on November 8, 1800. The two next transits, near the opposite node, will take place at the times of the oppositions in May 1905 and May 1984.

During the last half-century there have been *ten* transits of *Mercury* as seen from *Mars* (against *six* as seen from the Earth):

1836	July 27	1856	June 4*
37	Aug. 23*	57	April 15
38	July 3 (very short chord)	66	Sept. 5
47	Jan. 13*	76	Jan. 27
47	Nov. 23	77	Feb. 21*

the four marked with an asterisk being near the descending node, the others near the ascending node of the orbit of *Mercury* on that of *Mars*.

Venus has crossed the Sun's disk four times:

1830	May 15	1862	May 15
34	Dec. 27*	66	Dec. 25*

On the other hand, *Mars* itself has crossed the Sun's disk, as seen from *Saturn* or *Saturn's* satellites, 1831, July 25 (short chord), and 1847, July 26. It has been in transit for *Uranus* and its satellites 1851, July 25, and 1853, June 24 (apparent diameter of Sun 97″·4, of ♂ 0″·5), and for *Neptune* and its satellite 1860, October 25, and 1862, September 19, (apparent diameter of Sun 64″·4, of ♂ 0″·3). The reason that there have not been more transits for *Neptune* than for *Uranus* is found in the cir-

consistency that the inclination of the orbit of Mars to that of Neptune is double that of the orbit of Mars to that of Uranus. Otherwise transits will in general be the more frequent, the farther the outer planet is away. There has been no transit of Mars for Jupiter and Jupiter's satellites during the last half-century. The last transit occurred August 13, 1785, the next one will take place, I presume, in April 1886.

Though these statements respecting transits across the Sun's disk, as seen from or occasioned by the planet Mars, may possess no direct practical interest, they will perhaps facilitate the formation of correct and distinct notions concerning this class of invisible phenomena, and their communication may therefore not be without interest for some readers.

On the Change in the Mean Error of Longitude of Hansen's Lunar Tables since 1876. By W. T. Lynn, B.A.

At page 12 of his last Annual Report to the Board of Visitors, the Astronomer Royal expressed the opinion that the error of longitude of Hansen's Lunar Tables, instead of continuing to increase as it had done for several years previously, was on the whole somewhat smaller in 1878 than it had been a year or two before. I have put this to the test of figures, by computing the mean error from the Greenwich observations made with both the Transit-Circle and Altazimuth in 1878, and comparing it with that from the observations in 1876, as given in my paper in the *Monthly Notices* for last March (page 369). The Astronomer Royal gives me permission to make public the result from the observations for 1878, which are not yet published, and I am thereby enabled to exhibit the following comparison, proving that the mean error of longitude was in fact then decreasing, as it probably is still :—

1. From Observations with the Transit-Circle—

Year.	No. of Observations.	Mean Error of Longitude for the Year.
1876	82	+9″·72
1878	90	+8·23

2. From Observations with the Altazimuth—

Year.	No. of Observations.	Mean Error of Longitude for the Year.
1876	171	+9″·31
1878	161	+7·48

The sign + indicates, as usual in the *Greenwich Observations*, that the *Nautical Almanac* (Hansen's) place is too large. The largest mean error in the opposite direction was in the year 1862, which is given in my paper above referred to, and amounts to about −3″·20 from the mean of the results with the two instruments. From that time it appears to have been affected

by a positive change of about one second annually, so as to become practically insensible in 1865–6, and then to increase regularly until it became nearly 10″ in 1876–77.

Mean Areas of Umbræ, Whole Spots, and Faculæ upon the Sun's Disk as measured on Photographs taken at the Royal Observatory, Greenwich, for each Rotation of the Sun from 1873, *July* 11.

(*Communicated by the Astronomer Royal.*)

The Mean Areas have been formed by taking the Means of the Areas for each day of observation throughout each rotation of the Sun, and are expressed in millionths of the Sun's visible hemisphere.

No. of Rotation.	Date of Commencement of each Rotation.	Mean Area.		
		Umbræ.	Whole Spots.	Faculæ.
1	1873 July 11	237	1308	3773
2	Aug. 6	118	683	4539
3	Aug. 31	78	460	4295
4	Sept. 25	153	798	3036
5	Oct. 21	107	668	1719
6	Nov. 15	37	244	1356
7	Dec. 11	80	583	1456
8	1874 Jan. 5	199	1172	3251
9	Jan. 30	51	318	1688
10	Feb. 25	47	426	436
11	Mar. 22	71	532	282
12	Apr. 16	54	488	60
13	May 12	38	291	259
14	June 6	39	436	513
15	July 2	174	1192	1519
16	July 27	206	1341	1963
17	Aug. 21	34	248	1906
18	Sept. 16	127	904	1645
19	Oct. 11	42	227	794
20	Nov. 6	60	437	773
21	Dec. 1	17	138	255
22	Dec. 26	17	99	1197
23	1875 Jan. 21	21	107	1069
24	Feb. 15	120	653	620
25	Mar. 12	56	321	643
26	Apr. 7	81	547	706
27	May 2	22	138	190

No. of Rotation	Date of Commencement of each Rotation.	Mean Area.		
		Umbræ.	Whole Spots.	Faculæ.
28	1875 May 28	65	420	274
29	June 22	90	485	365
30	July 17	20	129	327
31	Aug. 12	24	128	598
32	Sept. 6	14	96	383
33	Oct. 1	17	98	259
34	Oct. 27	29	130	212
35	Nov. 21	78	377	164
36	Dec. 17	16	96	113
37	1876 Jan. 11	50	302	226
38	Feb. 5	66	348	318
39	Mar. 2	57	248	510
40	Mar. 27	8	40	324
41	Apr. 21	9	38	267
42	May 17	0	0	62
43	June 11	8	41	251
44	July 7	12	51	225
45	Aug. 1	7	28	80
46	Aug. 26	7	34	265
47	Sept. 21	34	136	209
48	Oct. 16	27	147	235
49	Nov. 11	37	130	163
50	Dec. 6	44	334	144
51	1877 Jan. 1	41	186	345
52	Jan. 26	13	64	131
53	Feb. 20	18	92	85
54	Mar. 17	8	41	320
55	Apr. 12	34	157	192
56	May 7	22	95	255
57	June 2	16	73	126
58	June 27	5	18	188
59	July 22	1	5	30
60	Aug. 17	21	102	217
61	Sept. 11	6	33	199
62	Oct. 6	35	187	46
63	Nov. 1	52	239	184
64	Nov. 26	27	115	75
65	Dec. 22	0	5	128

Many of the photographs taken during the ninth and five following rotations, i.e., between 1874, January 30, and 1874, July 2, do not show the faculæ with sufficient distinctness to allow of their measurement; the mean areas of faculæ given for these rotations are therefore too small.

Mean Areas of Umbræ, Whole Spots, and Faculæ upon the Sun's Disk, as measured on Photographs taken at the Royal Observatory, Greenwich, for each Year, from 1873 to 1877.

The mean areas are expressed in millionths of the Sun's visible hemisphere.

Year.	Mean Area.		
	Umbræ.	Whole Spots.	Faculæ.
1873	116	678	2882
1874	83	582	1096
1875	45	255	475
1876	25	132	226
1877	20	94	168

Many of the photographs taken during the early part of 1874 do not show the faculæ with sufficient distinctness to allow of their measurement; the mean area of faculæ given for that year is therefore too small.

The mean area of faculæ for the half-year beginning 1874, July 2, is 1257.

Note on Hyperion. By Prof. Asaph Hall.

This faint satellite of *Saturn* has the most eccentric orbit of any known satellite, and its distance from *Saturn* is such that, combined with the large eccentricity, it can approach very near *Titan*, the largest satellite of the Saturnian system. This peculiar orbit of *Hyperion* renders its motion interesting, as it will be the means of giving us an accurate knowledge of the mass of the Ring and of *Titan*. My observations of *Hyperion* during the present year, 1878, seem to put it beyond doubt that the line of apsides of the orbit of *Hyperion* has revolved at least a semi-revolution, or 180°, since the time of the discovery of this satellite in 1848, by the Bonds and Lassell.

The only observations of *Hyperion* that I know of are those made by the Bonds in 1848, two or three observations by Professor G. P. Bond in 1849, the observations by Lassell* and Marth in 1864, and those made at Washington since 1874. The old observations of this satellite will be valuable for determining its time of revolution and the motion of the line of apsides. If other observations exist than those mentioned above, I shall be indebted to anyone who will inform me of them.

U.S. Naval Observatory, Washington,
1878, *December* 27.

* 1850, *Monthly Notices*, xi., p. 62; 1852, xiii., p. 181; 1860, xx., p. 292.—Ed.

Observations of Meteors made on November 27, 1878. By Lord Lindsay and Dr. R. Copeland.

Curr. No.	Observer.	G.M.T. h m s	Size.	Began. R.A. °	Began. δ °	Ended. R.A. °	Ended. δ °	Remarks.
1	R. C.	10 24 0	...	39·5	+38	39·5	+34	
2	R. C.	10 39 ±	...	15	+36	12·5	+35	
3	R. C.	10 49 ±	...	57·5	+32·5	41	+35	
4	R. C.	10 50 30 ±	...	...	...	...	...	In *Cancer*, moving to the left, downwards.
5	L.	10 55 ±	...	27	+22	5	+15	
6	R. C.	11 2 12	2	82	+24	68	+13·5	
7	R. C.	11 6 7	3	28·5	+42	14	+37·5	
8	R. C.	11 8 50	...	...	...	...	...	Seen in *Gemini*.
9	R. C.	11 9 55	4	43	+28	50	+31	Path uncertain.
10	L.	11 27 0	2	57·5	−14	74	−23	
11	R. C.	11 55 50	...	65	+17	33	− 4	Path uncertain.
12	L.	11 59 ±	...	57	+32	40	+29	Path somewhat uncertain.
13	R. C.	12 17 35	...	...	...	...	...	Seen in *Ursa Majoris*.
14	R. C.	12 20 5	...	...	...	...	...	Seen in *Leo*.
15	R. C.	12 21 30	...	...	...	...	...	Seen in *Leo Minor*.

16	L.	12	21	45	...	76	+46	110	+35	
17	R. C.	12	28	20	2	112	+31	131	+48	
18	L.	...		...	...	...	...	...	...	Seen.
19	L.	12	28	59	2	48	+49	43	+ 4	Moved on this line.
20	L.	12	36	35	...	79	+28·5	...	...	Nearly stationary; moved in direction 135° of position.
21	R. C.	12	42	29	3	106	+15	115	+12	
22	L.	12	44	45	...	66	+45	52	+43·5	Path about 10° long.
23	R. C.	12	50	30	3	105	+ 6	93·5	0	
24	L., R. C.	16	50±		...	130	− 1	148	+ 2	
25	L., R. C.	16	52	0	1	113	+ 6	117	− 4	
26	L., R. C.	16	55	40	2	11	+62	11	+54	
27	L.	17	1	33	3	82	+45	77	+48	
28	R. C.	17	1	51	2	84	+40	90	+35	
29	L.	17	3	45	...	15	+35	11	+60	Moved on this line.
30	L., R. C.	17	8	48	...	114	+28	112	+23	
31	L.	17	9	32	...	222	+75	76	+46	Moved on this line.
32	L.	17	18	19	...	20	+88·5	12	+60	Moved on this line.
33	L.	17	26	22	...	20	+88·5	319	+62	Moved on this line.
34	C.	17	35	17	2	107·5	+22·5	97	+16	
35	L.	17	37	15	2	183	0	182	−16	

Observations of Meteors made on November 27, 1878—continued.

Curr. No.	Observer.	G.M.T.	Size.	Began. R.A. °	Began. δ °	Ended. R.A. °	Ended. δ °	Remarks.
		h m s						
36	R. C.	17 41 58	3	90	+42	85	+46·5	
37	L.	17 45 12	2	113	+ 6	83	− 3	Moved on this line.
38	R. C.	17 46 47	2	74	+53	67	+47	
39	L. C.	17 51 8	2	111	+65	111	+55	
40	L.	17 51 39	1	81·5	+21	66	+16	Slowish.
41	L.	17 54 30	3	81·5	+21	54	+24	
42	R. C.	17 55 35	2	45	+55	34	+48	
43	L.	17 56 10	3	11	+60	54	+24	Moved on this line.
44	R. C.	18 8 53	2	82	+53	70	+48	
45	R. C.	18 20±	2	...	...	...	...	In *Crater*, moving southwards.

15 meteors emanate from a diffused radiant, at R.A. 96°, Decl. +23°.
7 belong decidedly to Heis's No. 19 in 0° +90°.
37 paths were entered on the map which is in the B.A. Atlas.

Scarcely a single meteor was seen which could be attributed to the Biela radiant, but as the period of the comet is about 6 years and 202 days, a return of the meteors would hardly be considered probable. In 1885, November 27 will fall only forty days short of two periods since November 27, 1872, and will afford the best chance that can occur during the remainder of this century.

Dun Echt Observatory,
Nov. 29, 1878.

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